Land of Sky Region
Economic Resilience Exposure Analysis

Phase I Report

June 2018

LAND OF SKY REGIONAL COUNCIL

ECONOMIC DEVELOPMENT COALITION Asheville-Buncombe County

UNC ASHEVILLE NEMAC National Environmental Modeling and Analysis Center

Disclaimer

This draft analysis is a working document and should not be considered final; all information contained herein is subject to change. The analysis is based on best available information for specific threats and assets at the time the analysis was conducted. Quantitative results presented herein are preliminary and are based on data with inherent uncertainties and generalized assumptions; site-specific evaluations of vulnerability and risk are beyond the scope of this assessment and should be reserved for a detailed evaluation of specific adaptation measures. Updates will be provided as new information is made available and key findings are re-assessed accordingly.

Suggested citation

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Executive summary

To become better prepared as it faces both existing hazards and a changing environment, the Land of Sky region of western North Carolina—which, for purposes of this project, includes the counties of Buncombe, Haywood, Henderson, Madison, and Transylvania—has undertaken a resilience planning process to consider threats and hazards to the region's economic development and transportation assets with a goal of becoming more resilient to them, and to integrate the results into a localized perspective for future planning purposes.

Using the "Steps to Resilience" from the U.S. Climate Resilience Toolkit and guided by UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC), representatives from the Land of Sky Regional Council, the Asheville-Buncombe County Economic Development Coalition, and the French Broad River Metropolitan Planning Organization invited participants from area counties and municipalities to attend a workshop held March 12, 2018, during which participants determined key regional economic development and transportation assets and examined climate and non-climate stressors leading to threats and hazards that could negatively impact those assets. NEMAC then performed an exposure analysis on a limited set of identified asset-threat pairs and presented initial findings in a follow-up workshop held May 22, 2018.

Final results of the full resilience assessment are intended for use and integration into individual communities' existing hazard mitigation, comprehensive, and emergency management plans. *The data presented in this preliminary assessment should be considered as draft information until it is reviewed and refined for use in each individual jurisdiction.*

Key findings from the exposure assessment include:

- Landslide exposure was assessed only for Buncombe and Henderson counties due to the unavailability of data for Haywood, Madison, and Transylvania counties. As landslides are a significant region-wide threat, those counties should consider an investment in landslide mapping.
- Retail properties are exposed to flooding across the region.
- Regional wildfire exposure is very high.
- Transportation and economic development are linked assets when examining exposure (and subsequent vulnerability and risk).

Introduction

Communities across the United States are dealing with impacts from more frequent weather and climate-related threats. Since 1980, there have been more than 200 billion-dollar weather and climate-related disaster events in the United States.[1] The scientific consensus, as reported in the third National Climate Assessment,[2] highlights the fact that the frequency of extreme weather events is increasing, and that they are expected to become even more frequent and severe in the future. To further exacerbate the issue, certain regions of the country are facing increased stressors not related to climate—such as population growth, development, and economic and demographic shifts.

To better address impacts related to these events and shifting realities, communities are incorporating resilience and adaptation into their municipal planning. Resilience planning considers ways that communities can prepare for climate- and non-climate-related impacts to protect people and community assets and best deliver key services.

To become better prepared as it faces both existing hazards and a changing environment, the Land of Sky region of western North Carolina is undertaking a resilience planning process to consider threats and hazards to the region's economic development and transportation assets with a goal of becoming more resilient to them, and to integrate the results into a localized perspective for future planning purposes.

To this end, the Land of Sky Regional Council partnered with UNC Asheville's National Environmental Modeling and Analysis Center, or NEMAC, to lead its planners and jurisdictional representatives through a series of workshops and activities aligned with the "Steps to Resilience" outlined in the U.S. Climate Resilience Toolkit.[3] This phased approach provides communities, municipalities, and organizations with a blueprint for climate resilience planning.

This report outlines activities undertaken by participants relating to "Step 1—Explore Hazards" and the beginning of "Step 2—Assess Vulnerability & Risks" of the Steps to Resilience.

Project teams

A core project team was assembled in October 2017 and included representatives from the Land of Sky Regional Council, the Asheville Chamber of Commerce/Asheville-Buncombe County Economic Development Coalition, and the French Broad River Metropolitan Planning Organization. The Land of Sky Regional Council was responsible for logistical coordination, information gathering, and participation in planning needed for this project. An invited participant team provided input and guided the analysis. A team from NEMAC provided facilitation of the process as well as technical support and scientific analysis.

Core project team

Erica Anderson	Economic and Community Development Director, Land of Sky Regional Council
Jon Beck	GIS Planner, Land of Sky Regional Council
Heidi Reiber	Director of Research, Asheville-Buncombe County Economic Development Coalition | Asheville Chamber of Commerce
Mary Roderick	Regional Planner, Land of Sky Regional Council
Lyuba Zuyeva	French Broad River Metropolitan Planning Organization Director

Participant team

Mark R. Burrows	Planning and Community Development Director, Transylvania County
Matt Champion	Senior Planner, City of Hendersonville
Crystal Johnson	Geological Engineer, North Carolina Department of Transportation
Nick Kroncke	Regional Planner, French Broad River Metropolitan Planning Organization
Jody Kuhne	Regional Engineering Geologist, North Carolina Department of Transportation
Sara Nichols	County Planner, Madison County
Josh O'Conner	Recreation Services Manager, Buncombe County
Autumn Radcliff	Planning Director, Henderson County
Amber Weaver	Sustainability Officer, City of Asheville
Tristan Winkler	Transportation Planner, French Broad River Metropolitan Planning Organization

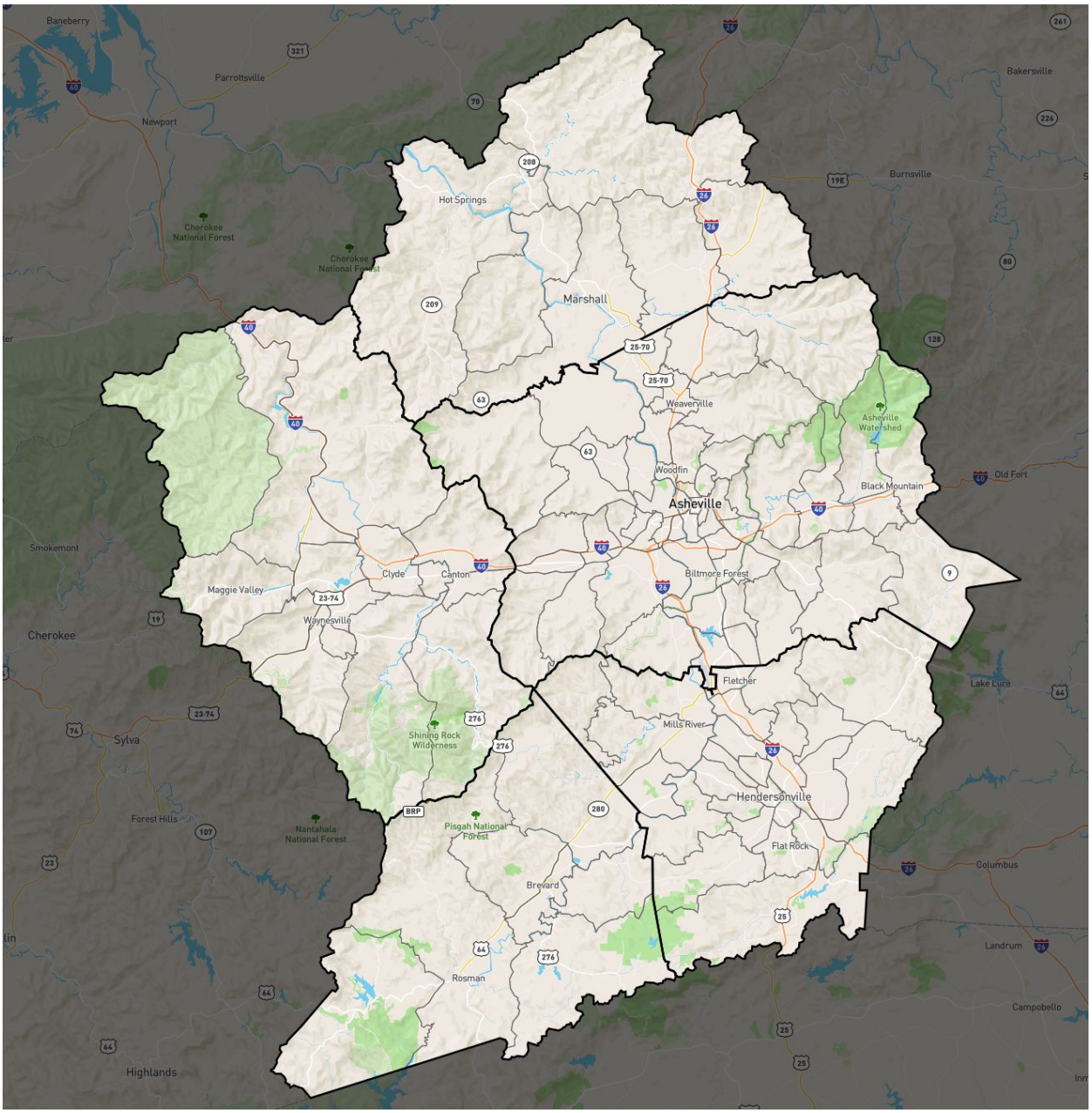
NEMAC team

Jim Fox	Director, Lead Facilitator
Nina Hall	Project Lead, Writer/Editor, Facilitator
Dave Michelson	Resilience Analyst, Facilitator
Matt Hutchins	Resilience Analyst
Karin Rogers	Resilience Analyst
Caroline Dougherty	Principal Designer
Kim Rhodes	GIS Associate/Cartography
Rachel Dunn	Writer (Student Intern)

The Land of Sky region

The project region—which includes the western North Carolina counties of Buncombe, Haywood, Henderson, Madison, and Transylvania and is referred to herein as the Land of Sky region—is one of the most diverse and beautiful areas in the country.

Extending from Tennessee to the north and the South Carolina border to the south, its topography ranges from fertile valleys to rugged mountains. The region is framed by the Blue Ridge Mountains to the east and the Great Smoky Mountains to the north and west.[4]



In total, the project area comprises around 2,420 square miles and had a 2016 estimated population of just under 475,000 people.[5]

The Land of Sky Regional Council desires to build resilience into its current and future plans, with an emphasis on economic development and transportation assets. By being proactive, the region can approach resiliency through a positive lens of opportunities rather than focusing on threats.

The purpose of the initial phase of the resilience project was to determine the threats on which to focus and to examine their potential impacts on the economic development/transportation asset set—how threats negatively affect these assets in the region. This phase also involved considering trends and future changes in climate conditions and determining exposure. The scope of the initial exposure analysis was limited to five asset-threat pairs.

From a review of regional planning documents, a handful of values and assets emerged as important, consistent, and vital to the way of life in the Land of Sky region. These assets contribute to the culture of the region, and in turn are highly valued. They include, in no particular order:

- Vibrant economy with backbones of tourism, agriculture, specialty manufacturing, and creative economy entrepreneurs
- Abundant natural systems
- Plentiful high-quality water supply
- Sustainable communities
- Productive farms and forests
- Cultural traditions, including clogging, bluegrass, pottery, and crafting

What is community resilience?

Resilience is defined as the capacity of a community, business, or natural system to prevent, withstand, respond to, and recover from a disruption.[2,6] In the southeast and across the nation, many local governments are recognizing the need to build resilience to increasingly frequent and/or severe extreme weather events.

One of the primary distinctions in the climate-related efforts made by local governments is the difference between climate mitigation and climate resilience or adaptation. *Mitigation* refers to the reduction of greenhouse gases that are causing climate change. *Climate resilience* or *adaptation* refers to the efforts taken to cope with and withstand the impacts associated with existing climate-related hazard events or events attributed to climate change. Many local governments already focus on mitigation through other "green" initiatives, such as energy conservation. However, there is an increasing realization of the need to also focus on resilience and adaptation, with the expectation that some degree of future change is unavoidable.

Specifically, resilience involves three considerations: (1) building resilience to current climate variability or past hazard events; (2) building resilience to recently observed changing trends in climate threats and non-climate stressors; and (3) building resilience to future projected changes in climate threats and non-climate stressors. Changes in climate will result in existing threats becoming more frequent and/or severe.[7,8]

Efforts to increase resilience to climate and non-climate impacts are built on the foundation of understanding—and reducing—vulnerability. *Vulnerability* is a ubiquitous term often used to describe susceptibility to harm. In the context of building climate resilience, a vulnerability assessment is a structured process that identifies ways in which an organization or community is susceptible to harm from existing or potential threats.

Vulnerability assessments tend to have three main components: (1) exposure; (2) potential impacts; and (3) adaptive capacity, where both physical and socioeconomic dimensions are considered. Another key concept used in a resilience assessment is the understanding of risk. Risk involves the likelihood and consequence of a climate threat.

Together, the concepts of vulnerability and risk within a resilience framework can serve to inform the development of strategies to reduce the vulnerability or risk. By taking an integrated viewpoint of these concepts, efforts can focus on building resilience for the assets that are most susceptible and most likely to be impacted. This approach also complements risk-hazard mitigation activities and management practices.

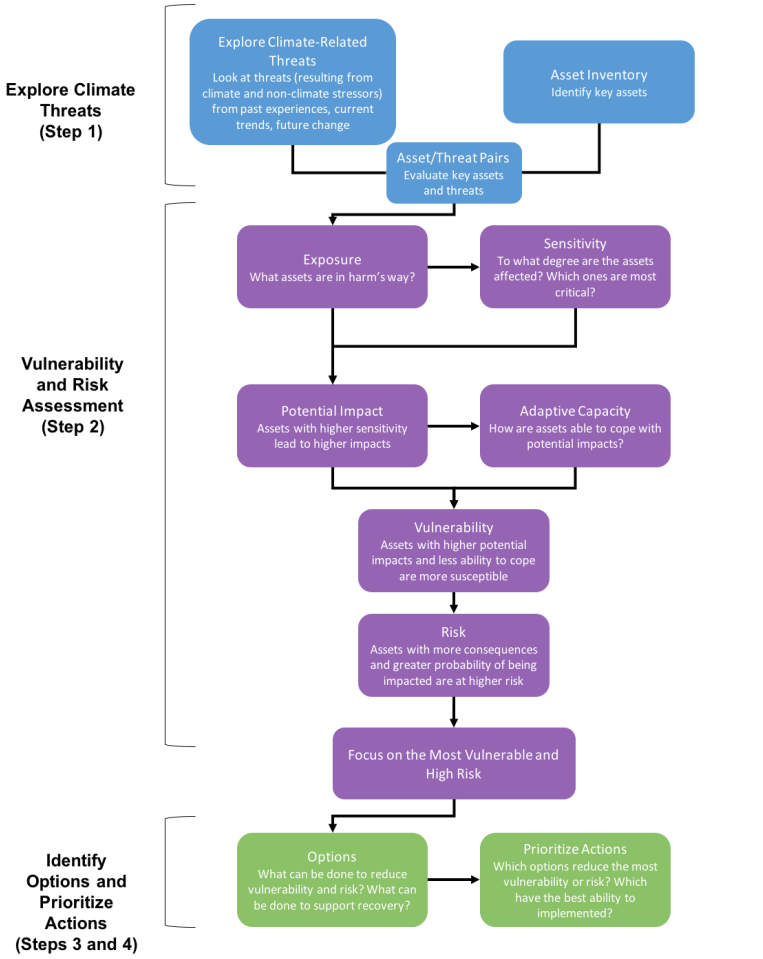
Another important aspect of a resilience assessment is to recognize the iterative nature of the process. Once strategies are implemented, it is necessary to monitor their effectiveness and to update the plan.

Overview of the "Steps to Resilience"

The U.S. Climate Resilience Toolkit[3] provides an iterative, five-step process for communities to follow when planning for climate resilience.

This framework—known as the Steps to Resilience—is used as the foundation of this resilience assessment. The framework integrates the components of climate resilience that can be used in existing jurisdictional planning processes at the local and regional level, and can be used to understand the characteristics of vulnerability and risk in a community, inform policy, and evaluate the effectiveness of strategies that are implemented.

Steps to Resilience and Supporting Components



Step One: Explore Hazards

Step One suggests that a community begin by researching its past experiences with climate and weather events and explore regional climate trends and projections to understand how assets (people, infrastructure, services, or resources) may be threatened. This is followed by identifying stressors—both climate and non-climate—that cause or contribute to a threat or hazard event and cataloguing key community assets

Step Two: Assess Vulnerability and Risks

Step Two moves into a vulnerability assessment. The purpose of this step is to understand how a community's assets are likely to be impacted by the climate threats identified during Step One; the assessment then becomes the foundation for developing options to build resilience in Step Three.

Step Two begins by determining which of the assets identified in Step One could be impacted by a threat or hazard—those that have some level of "exposure." *Exposure* is simply the presence of assets in places where they could be adversely affected.

Note that this report focuses on Step One and the exposure analysis portion of Step Two.

Vulnerability is defined as the susceptibility of societal assets to be impacted due to both physical and social factors. To define vulnerability, the assessment uses the exposure analysis to examine both potential impact and adaptive capacity. This can be thought of simply as *vulnerability = potential impact – adaptive capacity*.[2,6,9]

> *Potential impact* includes evaluating sensitivity, or the degree to which exposed assets are potentially affected.
>
> *Adaptive capacity* is the ability to cope with identified impacts with minimal disruption or cost.

Vulnerability is then determined by considering both the potential impact and the adaptive capacity, with the most vulnerable having the highest potential impact and the lowest adaptive capacity.

For areas with high vulnerability, it is then necessary to scope the level of risk. Risk depends on both the probability of an event happening and the consequence of that event. That is, what is the chance of a loss? It is important to note that the scoping of risk at this stage is not the same as undertaking a detailed risk assessment, which can be a time- and cost-intensive process. Instead, risk scoping is an initial broad quantification of risk that can be used to compare general probabilities and consequences of certain threats occurring.

Step Three: Investigate Options

The ultimate goal of Step Three is to have actionable options to build resilience for the assets that are most vulnerable and at-risk. To be actionable, an option should have the potential of building resilience by (1) reducing exposure (removing assets from harm's way), (2) increasing adaptive capacity (increasing the asset's ability to cope with impacts), or (3) supporting response and recovery.

Step Four: Prioritize and Plan

Step Three often yields a large number of options, and it can be difficult to evaluate and compare them all. Prioritization is a two-part process, the first of which involves looking at the actions that will have the most impact. The second part of the prioritization process is to determine criteria on which to rank the options.

Step Five: Take Action

Step Five can be viewed as the most important, as it involves implementing the plan to build community resilience. This step can take years to fully implement, and it is critical for the community to monitor results as time passes—some of the assumptions made during the original analysis may have been faulty, or on-the-ground implementation may not have been completed. This is to be expected, and the community should be open to modifying its approach as needed.

Step 1 | Explore threats & hazards

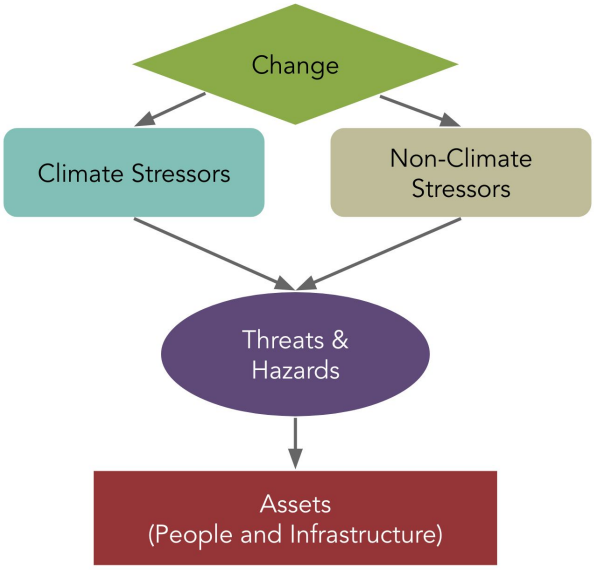
So that communities can understand climate-related impacts to make informed decisions, those impacts must be evaluated and measured in a structured way. To begin the evaluation, we ask four primary questions:

1. What is the normal regional climate?
2. What is changing or likely to change in the regional climate?
3. Will any of these changes cause an increased impact on things residents care about?
4. Is the Land of Sky region resilient to these threats (based on past events and possible future)?

To address these questions, it's best to break the system into its basic building blocks. One way to visualize these building blocks and see how they are related to one another is called a conceptual model—a technique that can be used to explore the causal relationships between stressors, threats, and assets that are potentially affected.

This conceptual model framework (right) illustrates the relationships between climate and non-climate stressors, threats and hazards, and assets that may be affected. The arrows in the model are drawn to reflect the causal influences between these different components.

This type of model can also be used to reveal strategies or actions (not shown) that have the potential to reduce vulnerability and build resilience.



As shown in the conceptual model, climate threats and hazards are the result of the interaction between climate and non-climate stressors. For example, the amount of precipitation (or lack thereof) in and of itself is not a threat. However, extreme precipitation is a climate stressor if enough precipitation falls in a given time, or in combination with a substantial amount of impervious surface that can lead to the threat of flooding. Likewise, the lack of precipitation (i.e., drought) is a climate stressor that can lead to the threat of water shortage.

Note also that threats and hazard events occur only where assets are potentially negatively affected. If an asset is potentially affected negatively by a threat (i.e., the asset is in harm's way), then it is considered exposed to that threat.

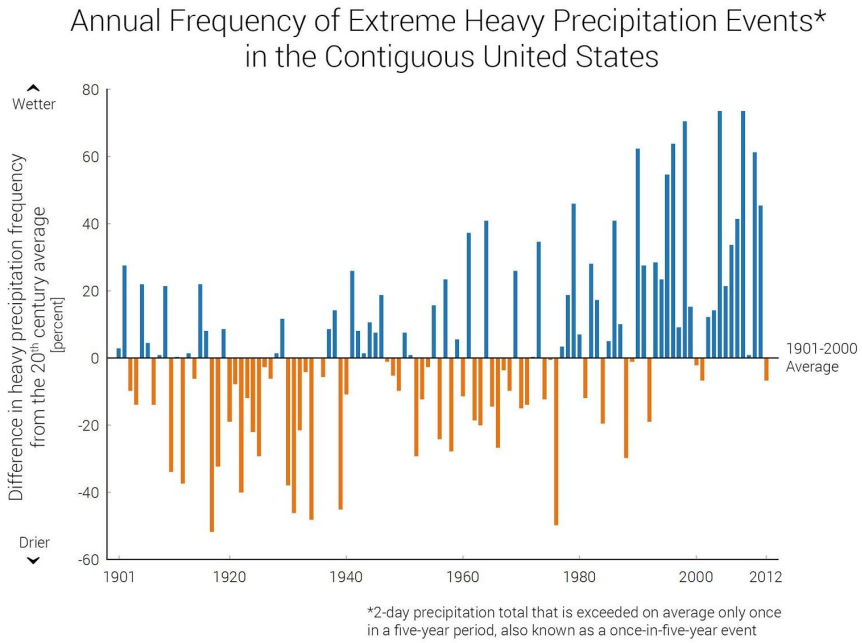
Climate stressors

The primary climate stressors for the Land of Sky region are heavy precipitation events, drought, and temperature variability.

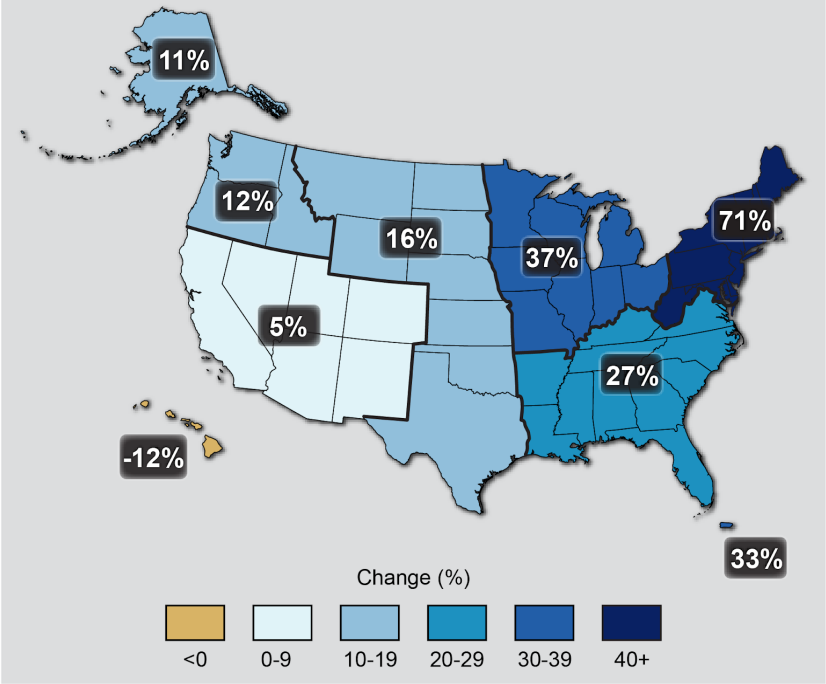
Heavy precipitation events

Overall, trends in precipitation are changing not only in the Southeast but nationwide, and contribute to climate threats such as flooding and landslides. The frequency of extreme heavy precipitation events (once in a five-year period) in the contiguous United States is increasing compared to the twentieth-century average. Also, according to the third National Climate Assessment, from 1958 to 2012 the Southeast region experienced a 27 percent increase in the heaviest one percent of precipitation events.[2] These national and regional trends show the importance of considering how extreme precipitation events impact communities.

The chart shows the difference in heavy precipitation frequencies from the twentieth-century average for the contiguous United States from 1901 to 2012. (Figure source: NOAA NCDC/CICS-NC[2])



Observed Change in Very Heavy Precipitation

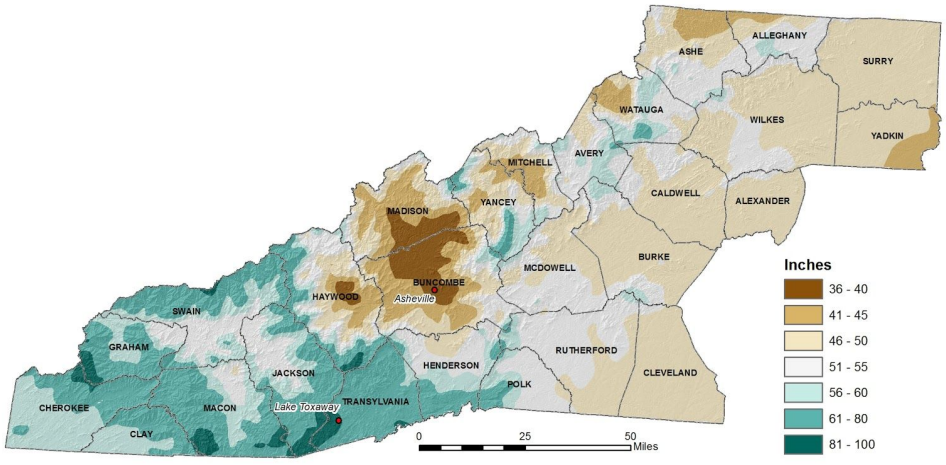


The map shows percentage increases in the amount of precipitation falling in very heavy events (defined as the heaviest one percent of all daily events) from 1958 to 2012 for each region of the continental United States. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: NOAA NCDC/CICS-NC,[2] updated from Karl et al. 2009)

Changes in the frequency of heavy precipitation events may be the largest climate stressor for the Land of Sky region due to the impact on flooding and landslides.

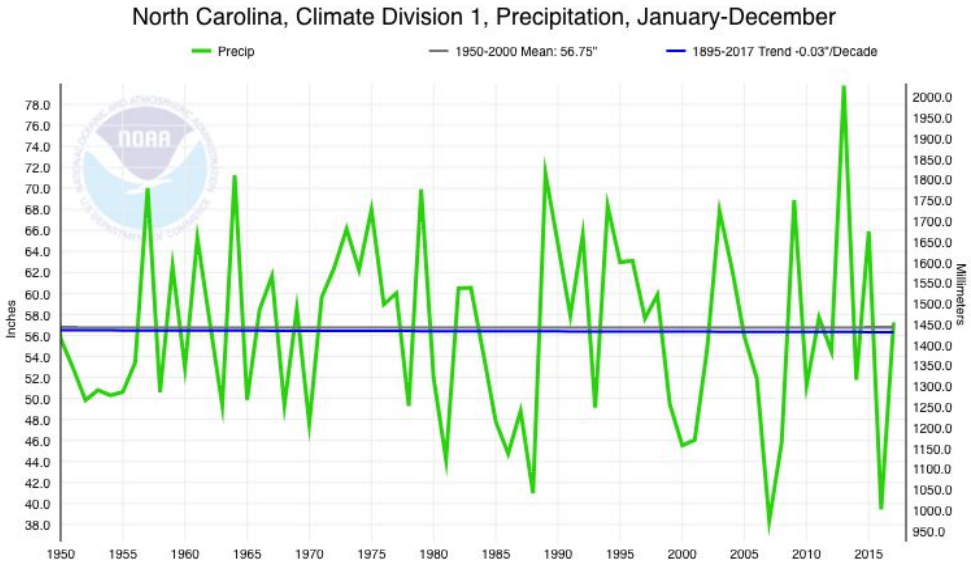
It's important to also consider where the rain falls. The map shows average precipitation in western North Carolina. Consider the two towns indicated by red dots—Lake Toxaway and Asheville—both in the Land of Sky region.

Average Annual Precipitation (1981 - 2010)



According to the State Climate Office of North Carolina, they are respectively the wettest and driest official weather recording stations in the region. Lake Toxaway, located in Transylvania County, has average annual precipitation of around 92 inches, and sits at the southern edge of

the Blue Ridge Escarpment. Moist air lifted over the mountains drops heavy amounts of rain on this high-elevation town; nearby areas are wet enough to be considered rain forests, and waterfalls abound. In contrast, the city of Asheville, in Buncombe County, has average annual precipitation of around 37 inches, and sits in the French Broad River basin. Shielded from the prevailing moist winds from the south and west by the Balsam and Smoky Mountains (where most of the rainfall is squeezed out), this area is the driest in the entire state of North Carolina. (Figure source: WNC Vitality Index)

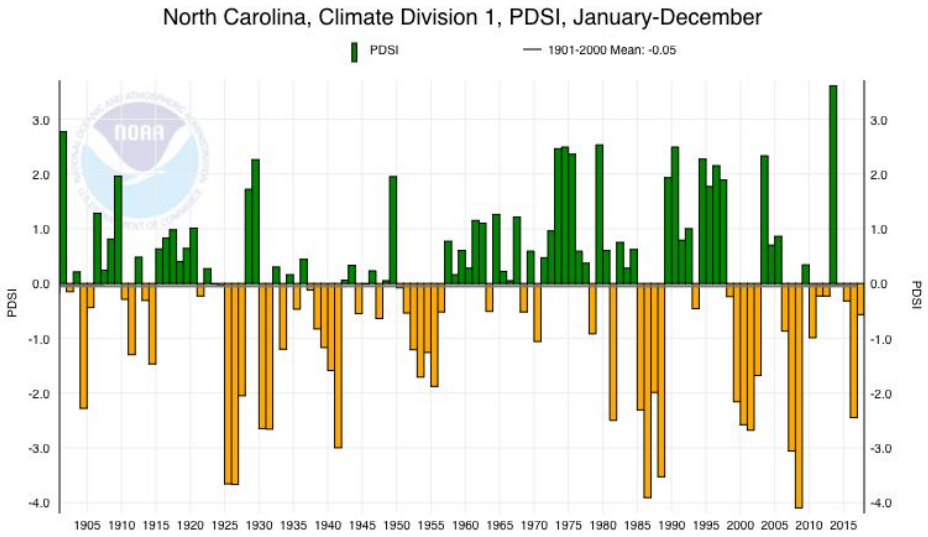


The chart at right shows that the area around the Land of Sky region has seen a very minor decrease in average annual precipitation since 1950—about 0.03 inches per decade. While the average may be mostly constant, the variability—especially the timing and severity of precipitation—is increasing. (Figure source: NOAA NCEI Climate at a Glance, U.S. Time Series)

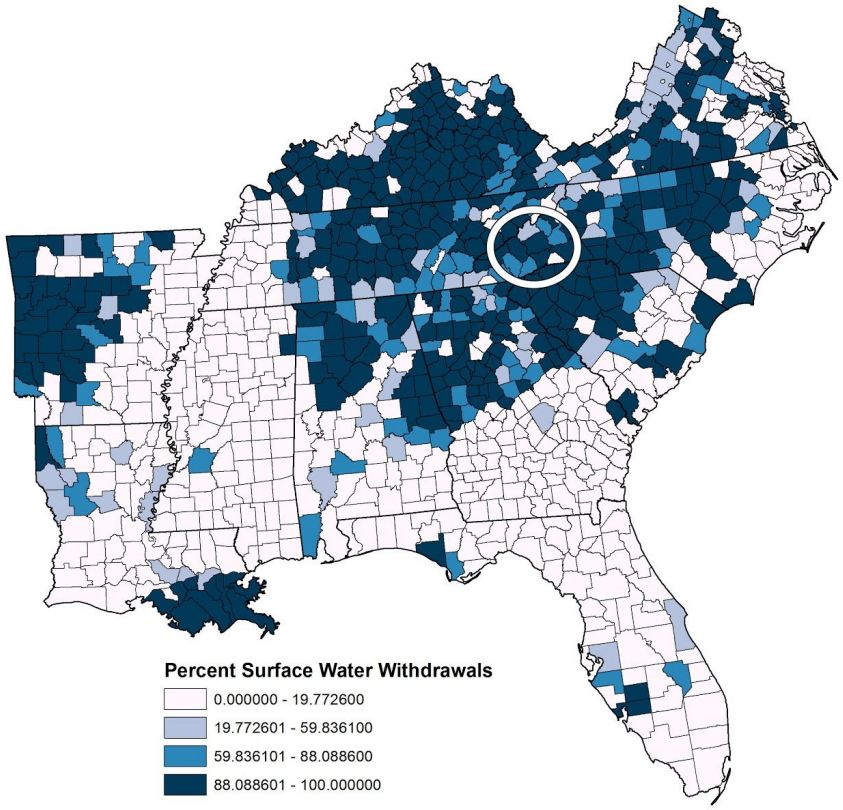
This underscores the need to move beyond an examination of average precipitation to a more detailed look at heavy precipitation events and drought and how these compare to one another.

Drought

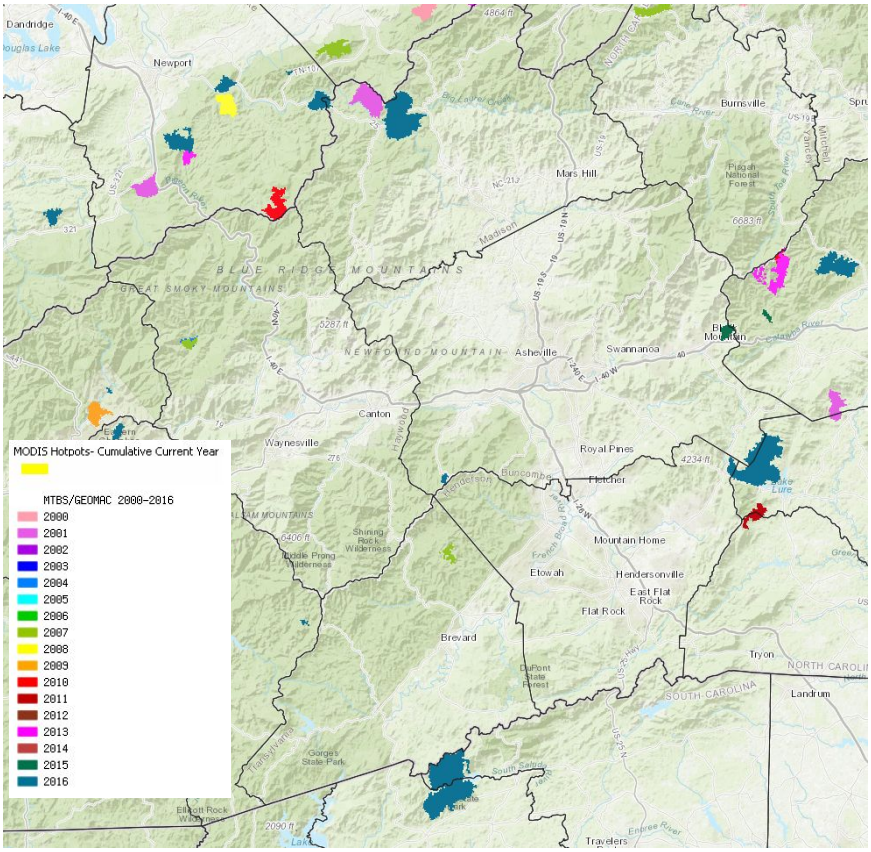
The Palmer Hydrological Drought Index for the area around the Land of Sky region indicates that droughts (indicated by the orange bars in the chart at right) are becoming more frequent and more severe. (Figure source: NOAA NCEI Climate at a Glance, U.S. Time Series)



In addition to precipitation variability, soil moisture may also decrease because of higher summer temperatures. This means that the Land of Sky region may want to consider planning for decreasing water availability, exacerbated by population growth and land use change. With increasing drought, surface water availability will be more limited. (Data source: U.S. Geological Survey)

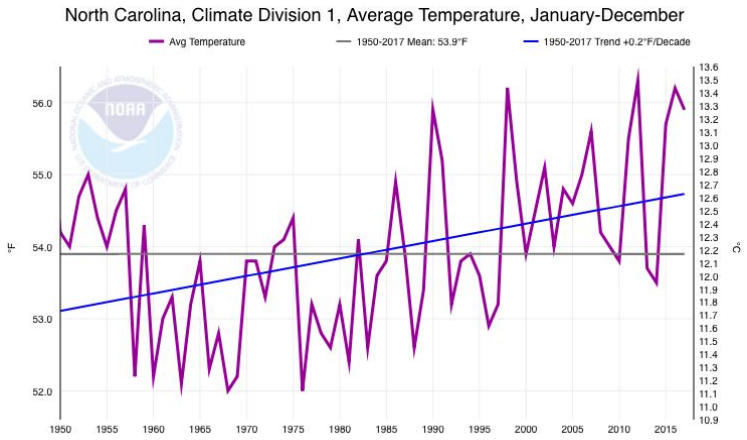


Increasing drought also increases the threat of wildfire. The peak wildfire season in western North Carolina is typically September through early December. Wildfire has a large impact on businesses and homes located in the wildland-urban interface. Additionally, smoke from wildfires impacts air quality, which in turn impacts human health. The map at right shows fire locations in the region since 2000. (Data source: U.S. Forest Service, Fire Perimeters and Hotspots)

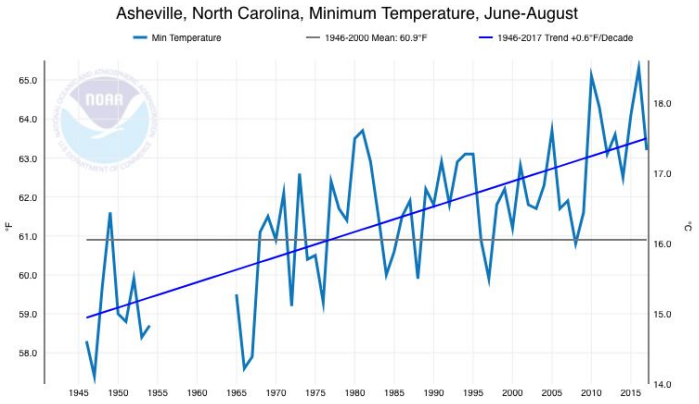


Temperature variability

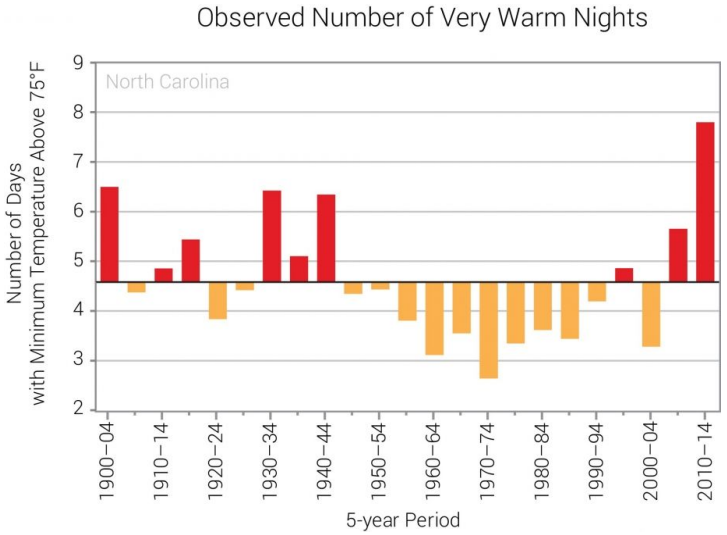
The average temperature for the region has been increasing since the mid-1980s; however, the increase is variable rather than a steady, year-to-year progression. This is the normal signature for cities across the Southeast: the trend shows an increase, with annual variability being the norm. (Figure source: NOAA NCEI Climate at a Glance, U.S. Time Series)



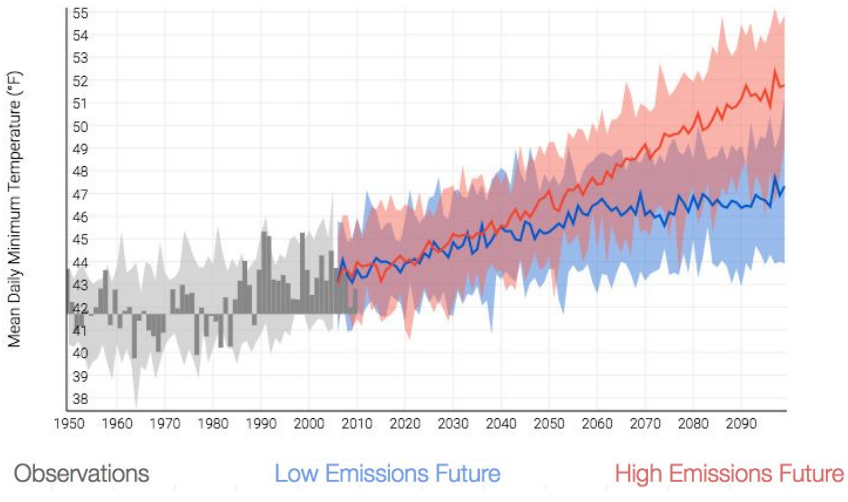
While the previous graph looks at average temperature, the graph at right shows minimum temperature during the summer (June–August). This indicates that summer nights are warmer than in the past. (Figure source: NOAA NCEI Climate at a Glance, U.S. Time Series)



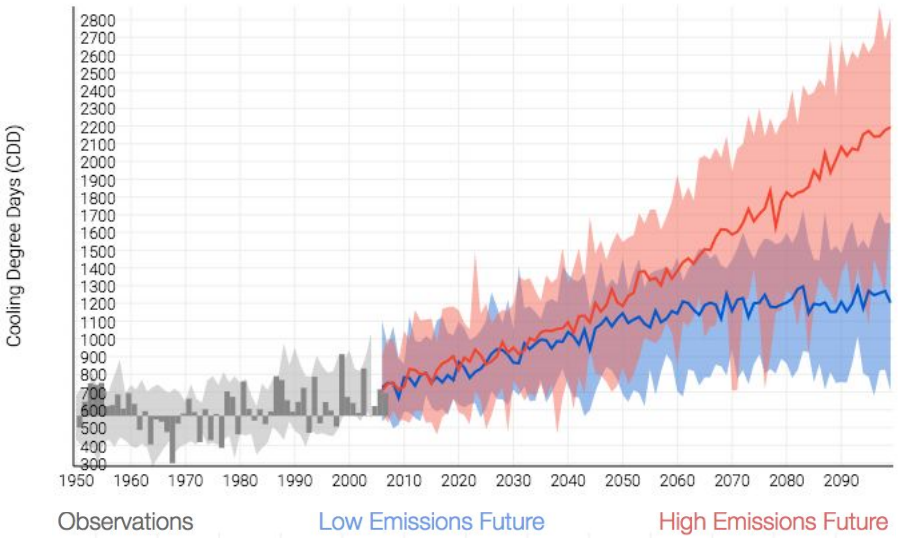
The number of very warm nights is increasing. From the mid-1940s to the mid-1990s, the number of warm nights during each five-year period was comparatively low; however, the number of very warm nights has risen since 2005. Because of this, many air conditioning systems now run continuously during many parts of the summer. (Figure source: NOAA NCEI State Climate Summaries, North Carolina)



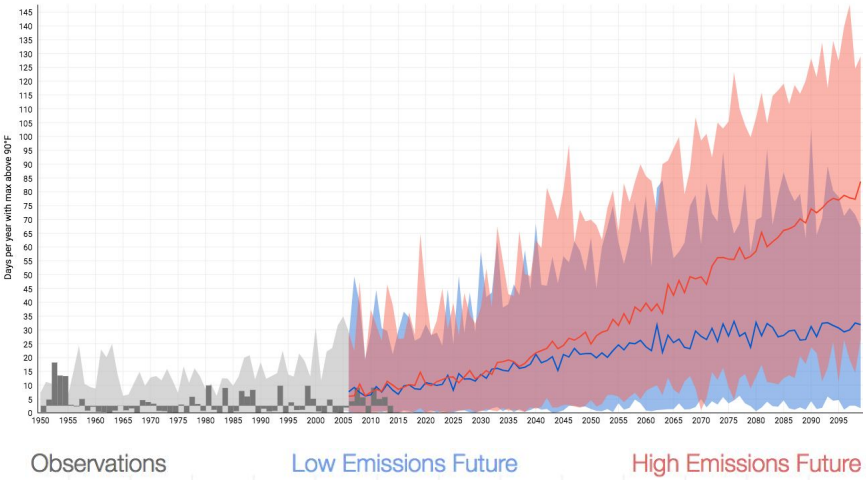
Projecting mean daily minimum temperature for the region into the future, the two main climate scenarios indicate that this warming trend will continue. Warmer summer nights will impact not only vulnerable populations—who may not be able to afford to cool their homes—but also put an increased demand on power providers. (Figure source: U.S. Climate Resilience Toolkit, Climate Explorer)



Another measure of temperature impact is cooling degree days, defined as the number of degrees by which the average daily temperature is higher than 65°F (cooling degree days) multiplied by the number of days this threshold is exceeded. This measure is a proxy that can show trends in expected energy demand for cooling.[10] In the Land of Sky region, the number of cooling degree days relative to the 1961–1990 average is projected to increase. (Figure source: U.S. Climate Resilience Toolkit, Climate Explorer)



Extreme heat may be the only threat with which we have limited experience in western North Carolina. The projected average increase in over-95°F days ranges from 0 to 10 for most of the western North Carolina region. The chart at right shows historical and projected days over 90°F for Buncombe County. (Figure source: U.S. Climate Resilience Toolkit, Climate Explorer)



Non-climate stressors

Both climate and non-climate stressors have the potential to change in the future and increase risk to economic development and transportation assets in the Land of Sky region. In some cases, changes to non-climate stressors can have greater influence on threats than climate stressors; however, some non-climate factors may help build resilience.

Non-climate stressors are factors or conditions that contribute to the occurrence of a threat. For example, impervious surfaces are a non-climate stressor and are known to contribute to increased runoff, erosion, and flooding in urban areas. Another example is that impervious surfaces and buildings also contribute to the urban heat island effect.

During Step One, the team identified key non-climate stressors facing the Land of Sky region. The challenges include:

- Population growth
- Land use conversion
- Median income
- Median home value
- Education level
- Commuting to work
- Water usage

In order to fully evaluate the impact of these non-climate stressors on the targeted economic development and transportation assets, the team must determine whether they are "valued and quantifiable." Thus, this analysis attempts to determine how these stressors might be changing with time—with special attention to a 30-year planning horizon—and how they interact with threats.

For purposes of the analysis, these stressors were represented by different metrics and data. These include:

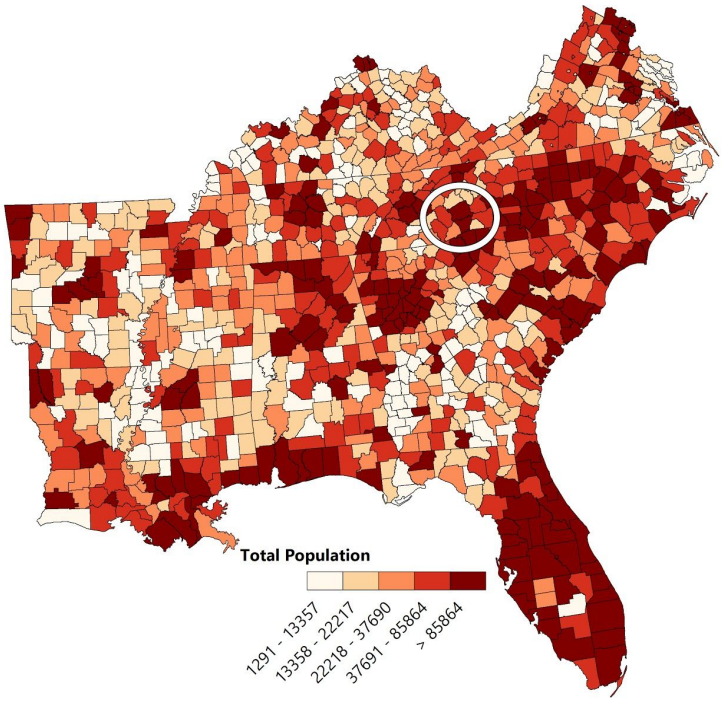
- Population and demographics: total population, population growth; and
- Economics: median income, educational attainment.

The following pages provide an overview of trends involving these non-climate stressors throughout the southeastern United States that can have implications for the Land of Sky region.

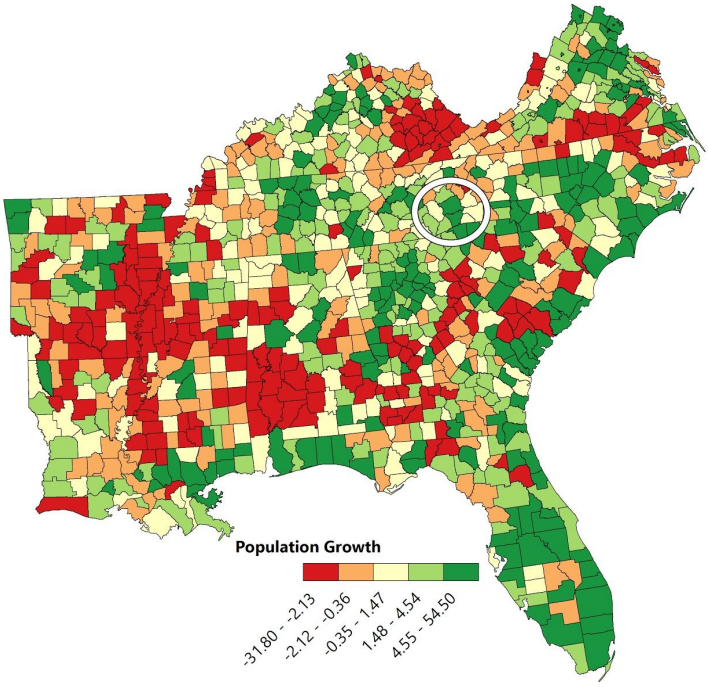
Population and demographics

While much of the country has experienced population growth over the past 50 years, the demographics of these areas are also changing. Demographic trends can often be explained by metrics related to growth and urban areas, median age, level of education, and similar factors.

A clear trend is seen when total population (right) is compared with population growth (below). The map at right shows the growth of urban centers in the Southeast, with a specific emphasis on suburban sprawl. Many counties in the Southeast have a relatively large total population that have also recently experienced high population growth. (Data source: U.S. Census Bureau, American Community Survey)



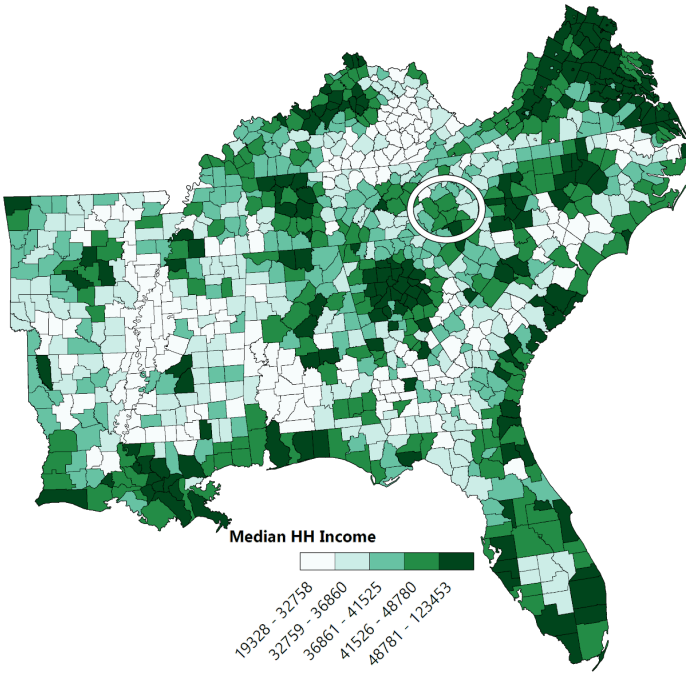
The Land of Sky region has particular demographic changes to consider. Buncombe County and Henderson County are in the highest growth category for the Southeast, and Transylvania County and Madison County are in the next highest. It should be noted that some other mountain counties are facing decreasing populations. This growth is largely the result of migration into the region, rather than changes to birth/death rates. (Data source: U.S. Census Bureau, American Community Survey)



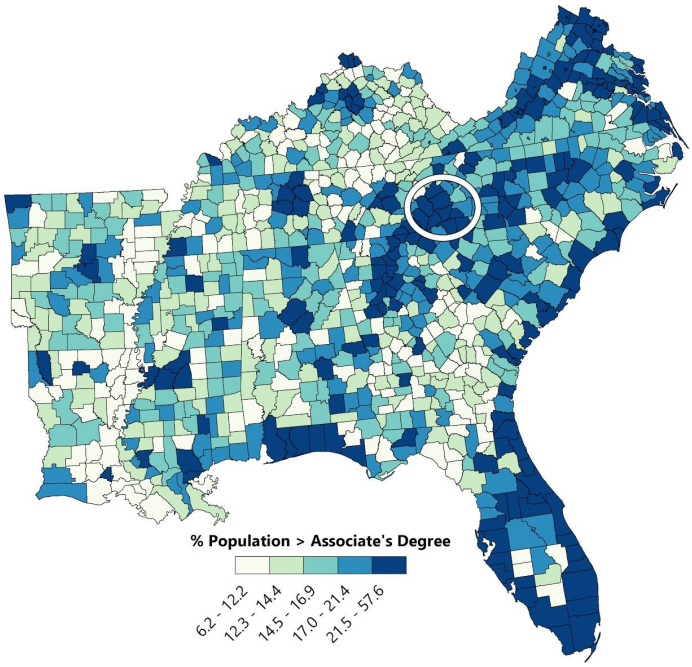
Economics

An economics lens can help to explain various trends related to non-climate stressors in the Land of Sky region. This category includes information related to the income levels and educational attainment and can inform the region's overall resilience when facing both climate- and non-climate-related threats and stressors.

County-level data from the U.S. Census Bureau shows that the Land of Sky region has a relatively high median household income compared to many counties in the Southeast. This is a positive factor that provides a "social advantage" when examining local residents' ability to take personal financial responsibility in building resilience. Note, though, that urban areas have a higher median income than rural areas within the region, and that the region as a whole has a lower median income level than other urban areas in North Carolina (such as Charlotte and the Triangle region around Raleigh) and in the Southeast as a whole (such as Atlanta). (Data Source: U.S. Census Bureau, American Community Survey)



Education level is an important metric when looking at the ability to implement complex solutions to build resilience. For the region, while urban areas have a more educated population, each county in our region has a very high level of educational attainment. This factor will help in local implementation of actions to build resilience. (Data source: U.S. Census Bureau, American Community Survey)



Climate-related threats

According to the NOAA Storm Events Database, between 1997 and 2017 there has been an estimated $159+ million in damage from climatic and extreme weather events in the Land of Sky region.[11]

It should be noted that NOAA's National Centers for Environmental Information, which produces the database, recognizes this as a partial record for some events and notes that in some cases the damages are broad estimates.

The table below summarizes these events. Note that the events in this summary at least partially took place in the Land of Sky region—thus some of the estimates may include damage totals that may have been reported from neighboring counties. This summary helps to identify the types of past events that have been most devastating.

Storm events that included the Land of Sky region from 1997 to 2017

Event Type	Count	Estimated Losses
Storms (Hail, Heavy Rain, High/Strong/Thunderstorm Wind, Lightning, Tornado)	1,144	$15,483,000
Flood/flash flood	232	$136,069,000
Winter weather (Blizzard, Cold/Wind Chill, Extreme Cold/Wind Chill, Freezing Fog, Frost/Freeze, Heavy Snow, Ice Storm, Sleet, Winter Storm)	388	$8,281,000
Drought	168	*
Wildfire	*	*
Total	1,933	$159,833,000

* Data not available

In an initial review of comprehensive and hazard mitigation plans, regional counties and municipalities have acknowledged that they are facing shared climate-related threats and hazards. Some of these include:

- Flooding
- Nuisance flooding, runoff, and erosion
- Landslides
- Wildfire
- Extreme heat events
- Water shortage
- Supply chain interruption

The threats and hazards selected for this analysis were limited by the scope of work, but are existing hazard events that have impacted the community in the past and have the potential to change in frequency or severity in a changing climate.

The table is an inventory of the threats addressed in the exposure analysis and their associated climate and non-climate stressors. This inventory was captured based on the project team's institutional knowledge of past events, the NOAA National Centers for Environmental Information Storm Events Database,[11] and regional climate trends and projections from the second and third National Climate Assessments.[2,12] The table is followed by a description of each of these threats.

Climate threats considered in the assessment

Climate Threat	Climate Stressor	Non-Climate Stressor
Flooding	Extreme precipitation	Impervious surfaces
Landslides	Extreme precipitation	Steep slope development and vegetation removal
Wildfire	Temperature variability, drought	Fuels and vegetation, human-caused ignitions

Flooding

Precipitation trends are changing both nationally and in the Southeast and contribute to climate threats such as flooding. For more information, refer also to the discussion of heavy precipitation events in the climate stressors section of this report, above.

For purposes of this assessment, the threat of flooding was defined by the flood hazard areas as determined by the North Carolina Floodplain Mapping Program (NCFMP)[13]; assets within any of these flood hazard zones were determined as being exposed to flooding.

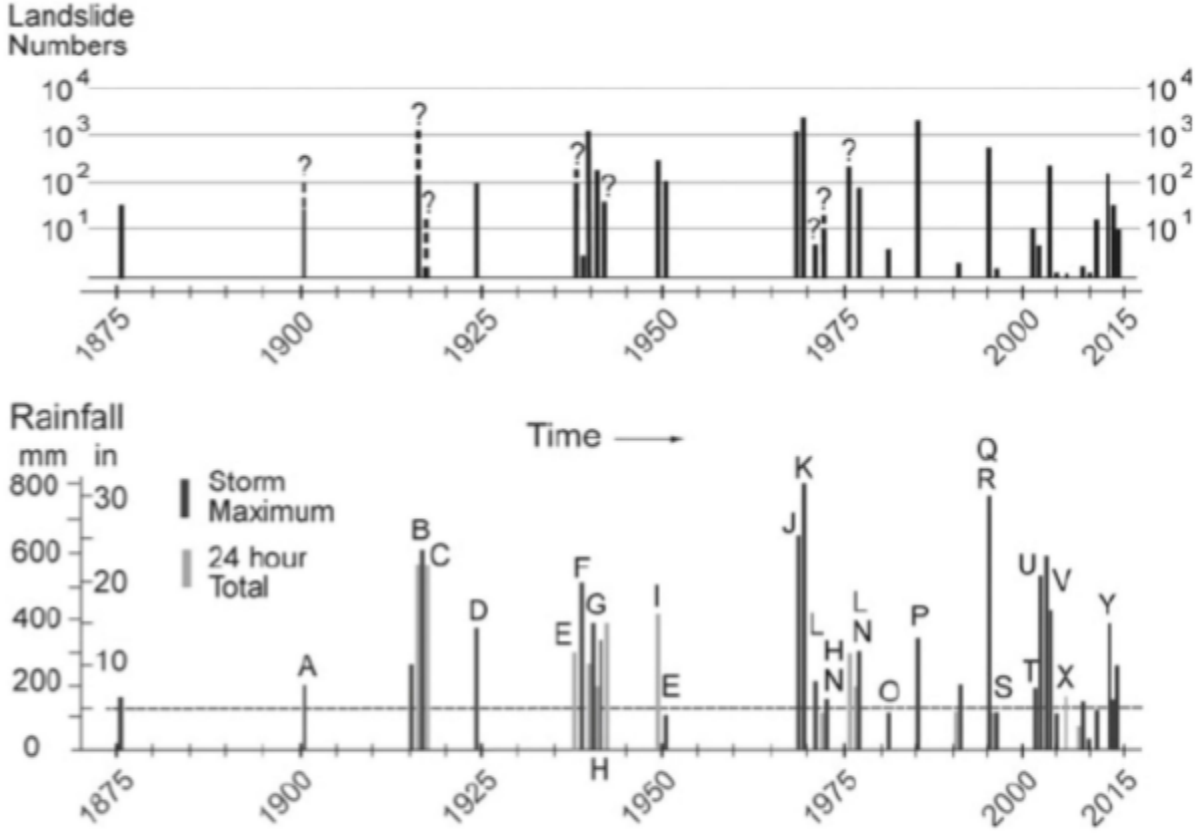
A 100-year flood event has a one-percent chance of occuring every year, while a 500-year flood event has a 0.2-percent chance of occuring in any given year.

The map of downtown Asheville and the River Arts District shows industrial parcels exposed to flooding. Exposed parcels are shown in yellow, while the floodway, 100-year floodplain, and 500-year floodplain are shown in varying shades of blue.

Landslides

Landslides in western North Carolina are, like flooding, associated with climate stressors related
to the amount and timing of precipitation. The primary non-climate stressors contributing to the threat of landslides are development and the removal of vegetation on steep slopes.

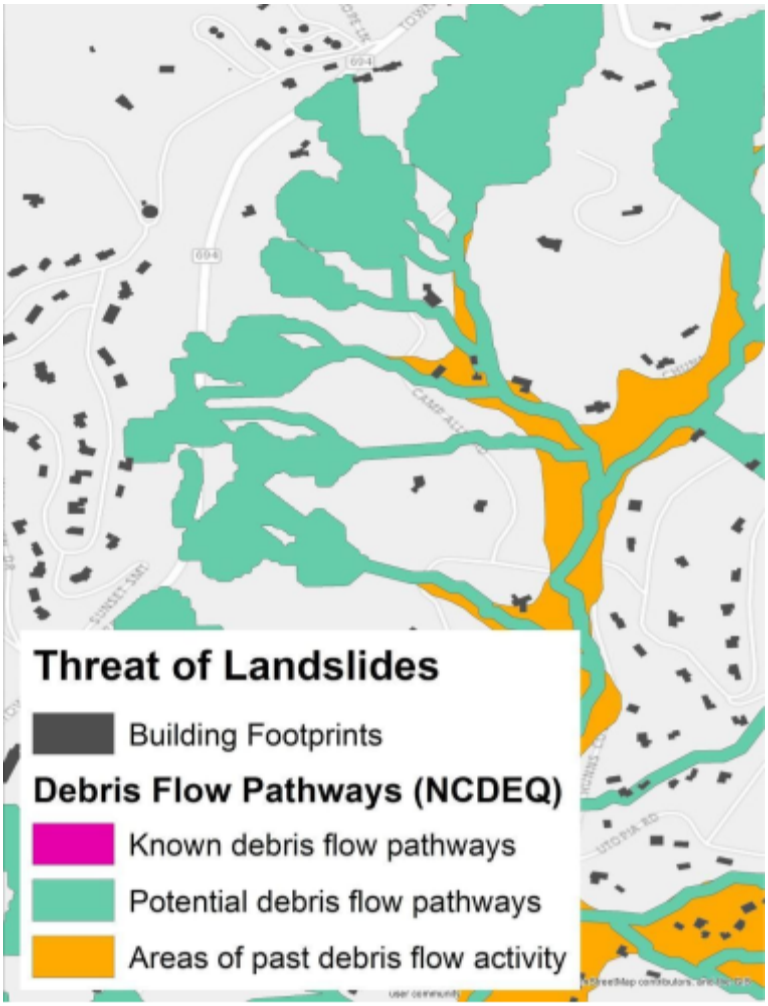
Landslide events include debris flows, rock slides, mudslides, earth slides, and movements.[14] Most of the loss of life associated with the 2004 precipitation events in the region was attributed to landslides that occurred throughout western North Carolina. Research by scientists and North Carolina state geologists have explored how landslide events in western North Carolina are often associated with certain thresholds of extreme precipitation. For example, it is estimated that four rainfall events in 2013 resulted in at least 300 landslide events in the region.[15] The chart below shows the rainfall amounts for selected storms that triggered landslides, mainly debris flows, in western North Carolina from 1876 through 2015.



The graphs show the association between amount of rainfall (bottom) and landslide numbers (top). Heavy rainfall events, especially those with at least 5-inch 24-hour totals, are associated with spikes in the number of landslide events. (Figure source: Wooten et al. 2016.)

For purposes of this assessment, the threat of landslides was defined by potential debris flow areas in Buncombe and Henderson counties, as determined by the North Carolina Department of Environmental Quality (NCDEQ).[16] Assets within any of these potential debris flow pathways were determined as being exposed to landslides.

Landslide exposure was assessed only for Buncombe and Henderson counties; data was unavailable for Haywood, Madison, and Transylvania counties.



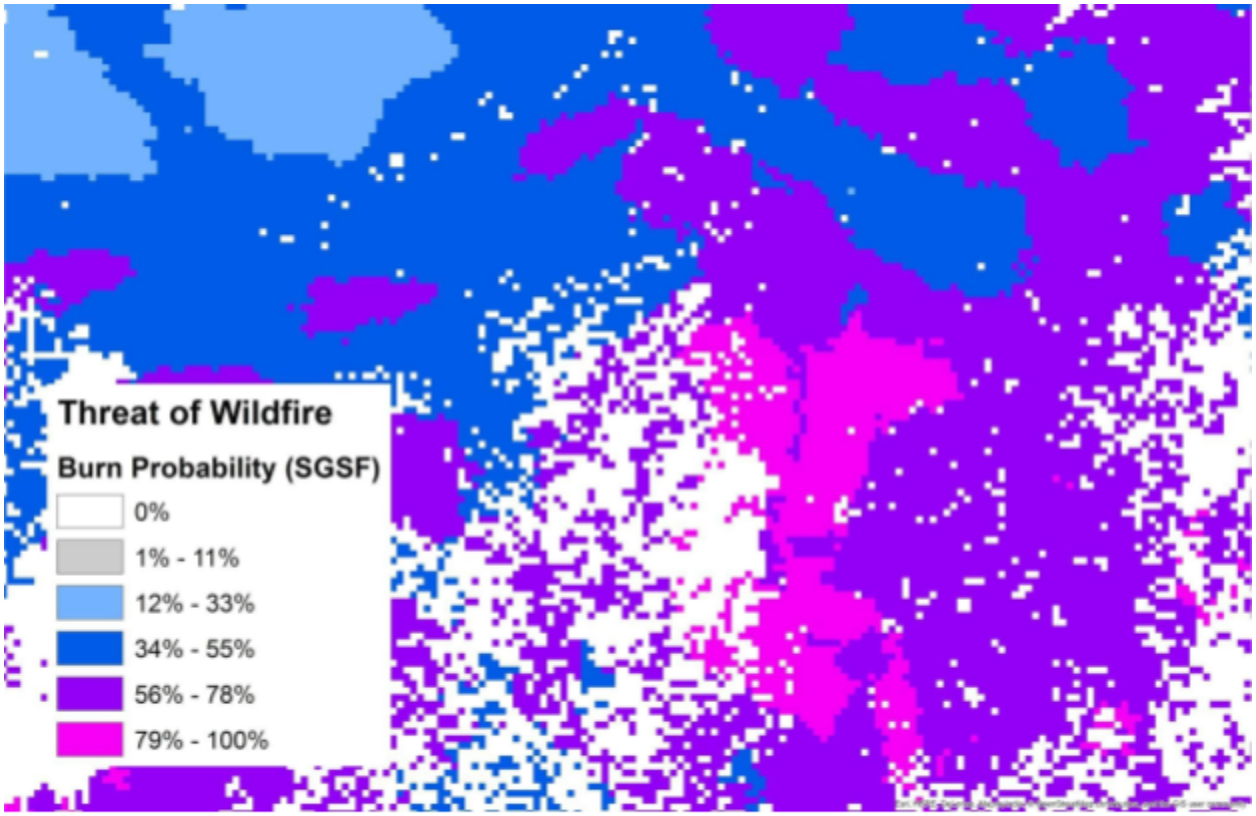
The map shows building structures just east of Town Mountain Road in Asheville, some of which are in potential debris flow pathways.

Wildfire

Wildfire is a natural disturbance that provides benefits to ecosystems and natural systems, but it can become a threat when it negatively impacts communities and the assets we value. Drought conditions can lead to a greater chance of wildfire.

The primary non-climate stressor related to the threat of wildfire is the management of fuels and vegetation. Lack of active fuel management can contribute to a decline in fire-resilient ecosystems, an increase in wildfire burn severity, and increased risk of destructive wildfires that damage landscapes and threaten people and communities.

The threat of wildfire was defined by areas with burn probability, as defined by the Southern Group of State Foresters (SGSF).[17] Assets within areas with any burn probability were determined as being exposed to the threat of wildfire.



The map of an area around Haw Creek in Asheville shows burn probability, which was used to evaluate the threat of wildfire. Any assets within areas of burn probability were determined as being exposed to the threat of wildfire.

Assets

Assets were identified by exploring the project team's institutional knowledge of shared types of assets as well as local comprehensive and hazard mitigation plans, but were limited by the scope of work. The following asset categories (broad) and the assets that define them (more specific) were used for the exposure analysis.

Assets considered in the assessment

Asset Category	Description
Properties	
Commercial Properties	Includes non-residential properties that serve businesses and organizations. They also typically support commerce, jobs, and tourism. Includes Retail, Office, Industrial, Institutional, and Utility parcels.
Transportation	
Roads	Includes all major and secondary roads and considers the road infrastructure potentially inundated and exposed to damage.

Step 2 | Assess vulnerability & risks—exposure analysis

Exposure is the presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.

This section of the report presents the results of an exposure assessment of spatially differentiable assets and threats in the Land of Sky region performed as the beginning of "Step 2—Assess Vulnerability & Risks" of the Steps to Resilience.

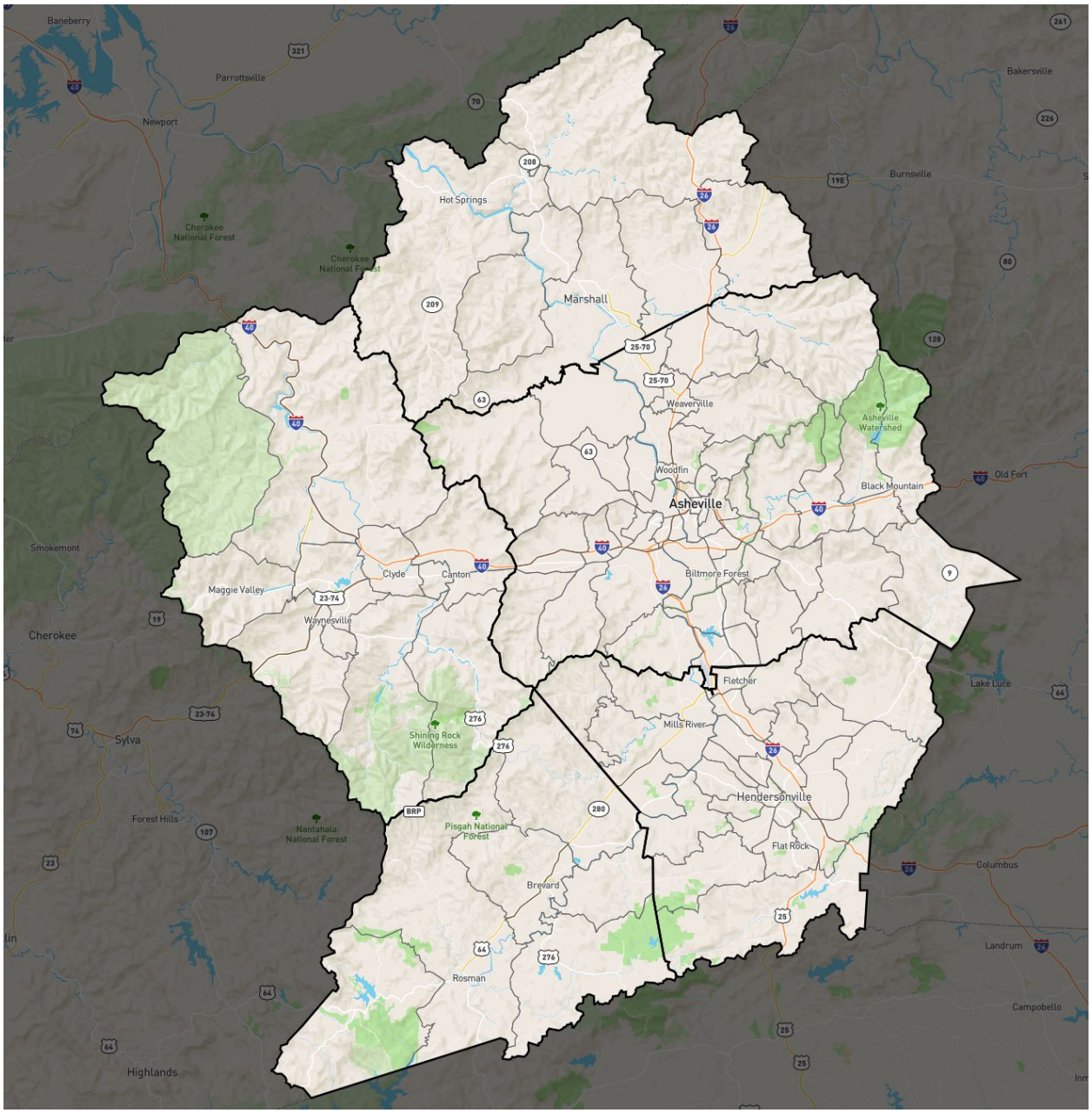
This exposure assessment can be used as the basis of any subsequent vulnerability assessment performed in the project's next phase.

For each of the identified major assets and threats, the spatial intersection was assessed to determine the proportion of asset categories that are exposed to specific threats. This assessment was performed at the specific asset level (e.g., a property parcel or road segment) and then aggregated to the census tract scale, enabling comparison with socioeconomic data. This process is further described in Appendix A.

Key findings from the exposure assessment include:

- Landslide exposure was assessed only for Buncombe and Henderson counties due to the unavailability of data for Haywood, Madison, and Transylvania counties. As landslides are a significant region-wide threat, those counties should consider an investment in landslide mapping.
- Retail properties are exposed to flooding across the region.
- Regional wildfire exposure is very high.
- Transportation and economic development are linked assets when examining exposure (and subsequent vulnerability and risk).

Regional scale overview



County boundaries
Census tracts

Assets

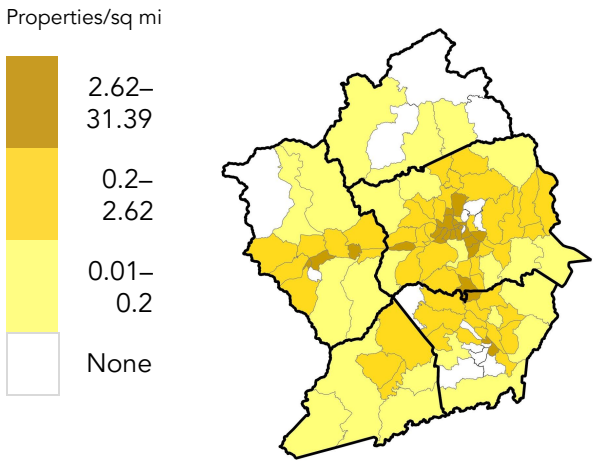
Key assets to be analyzed were (i) identified in collaboration with the participant team, (ii) limited by the scope of work, and (ii) selected after determining which of the identified assets could be quantified. The following list of asset categories (broad) and the assets that define them (more specific) were used for the exposure analysis:

Asset Group	Total Assets
COMMERCIAL PROPERTY	
Industrial properties	1,296 parcels
Institutional properties	3,926 parcels
Office properties	1,610 parcels
Retail properties	6,541 parcels
Utility properties	695 parcels
TRANSPORTATION	
Roads	9,947 miles

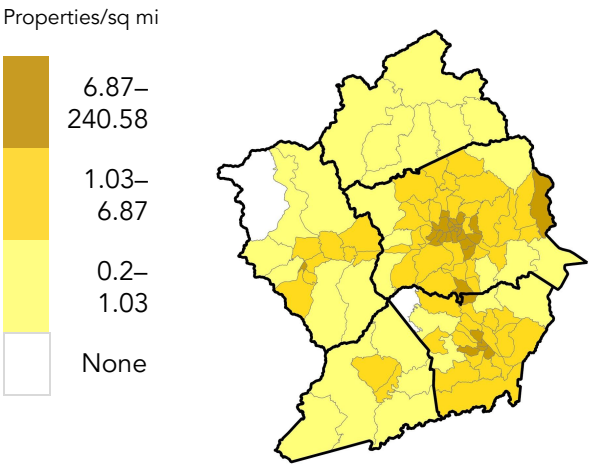
Note: In the maps below, colors indicate the total number of assets in each census tract; darker colors in larger tracts may be misleading.

COMMERCIAL PROPERTY

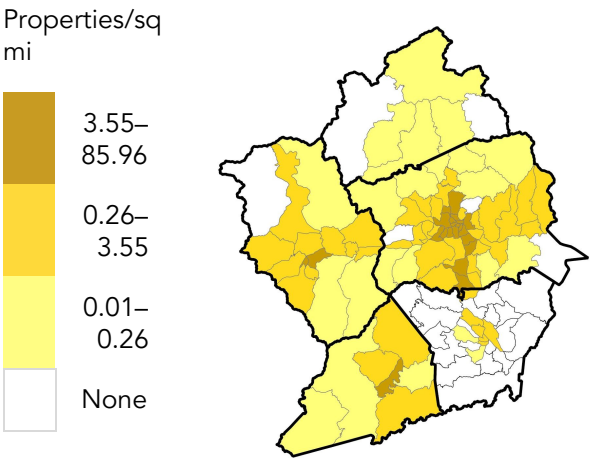
Industrial properties



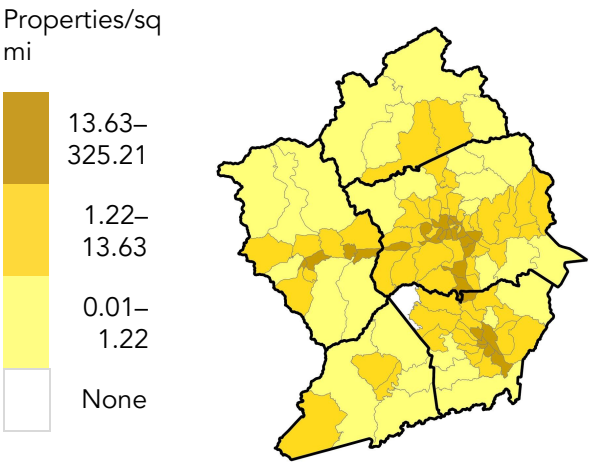
Institutional properties



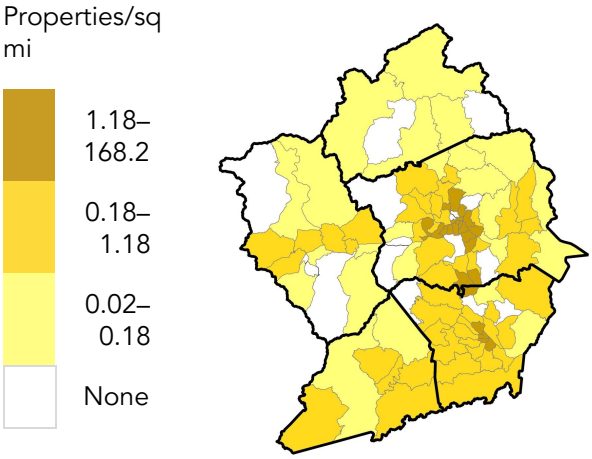
Office properties



Retail properties

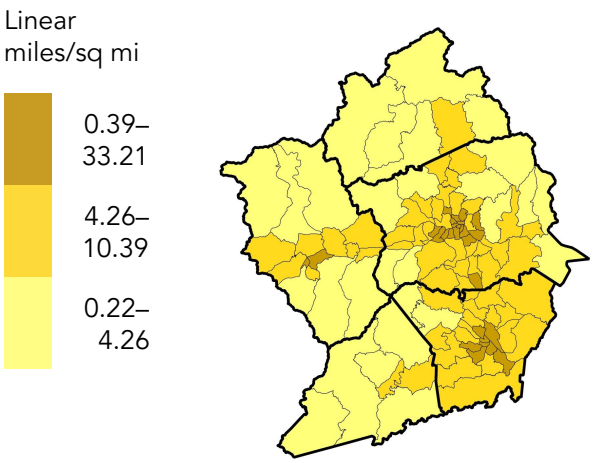


Utility properties



TRANSPORTATION

Roads

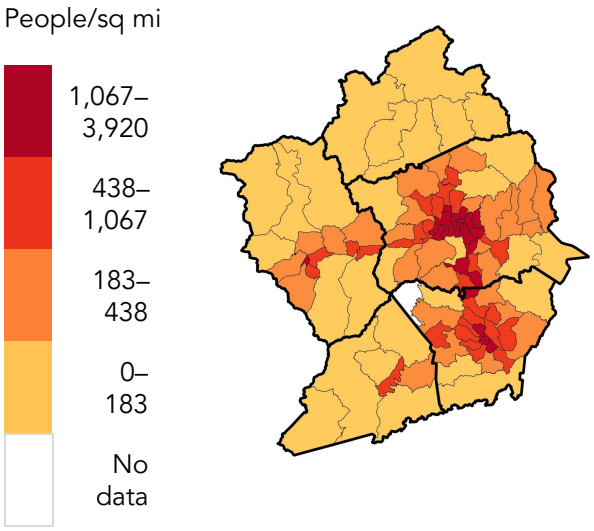


Demographics and socioeconomics

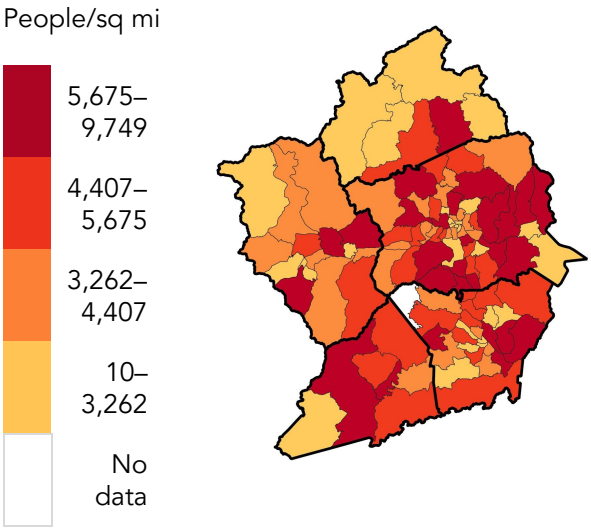
The U.S. Census Bureau and Esri's Business Analyst Online collect a variety of demographic, economic, and socioeconomic variables, and a number of these factors vary across the Land of Sky region. Several of these variables can be considered strengths: the region's population, for example, is well educated and enjoys a relatively high income level. Some of these factors, however, are challenges—urban areas have a higher median income than rural areas within the region, and the region as a whole has a lower median income level than other urban areas in North Carolina and in the Southeast. These factors should be used as a lens when examining equitable implementation of solutions.

Population and Growth

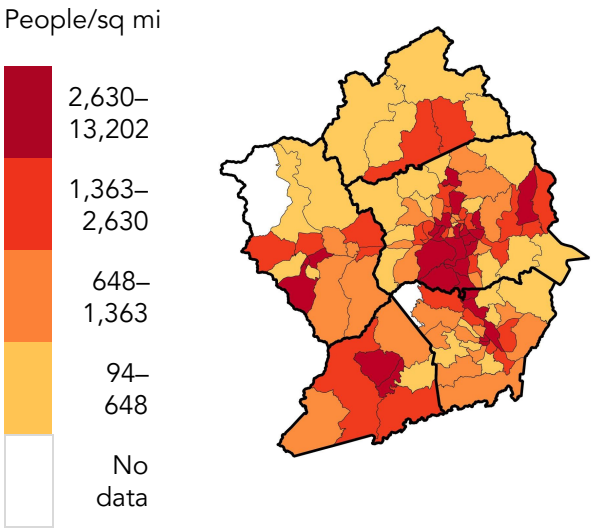
Population Density (2017)



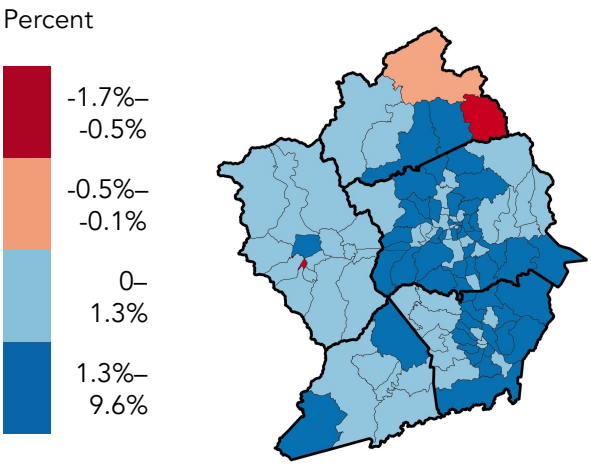
Total (Nighttime) Population (2017)



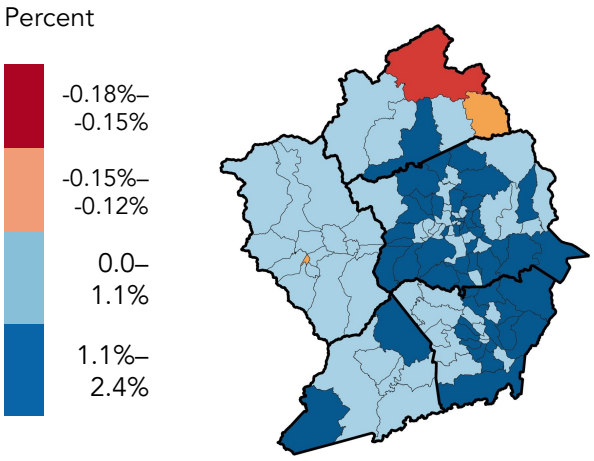
Daytime Population (2017)



2010–2017 Population: Annual Growth Rate

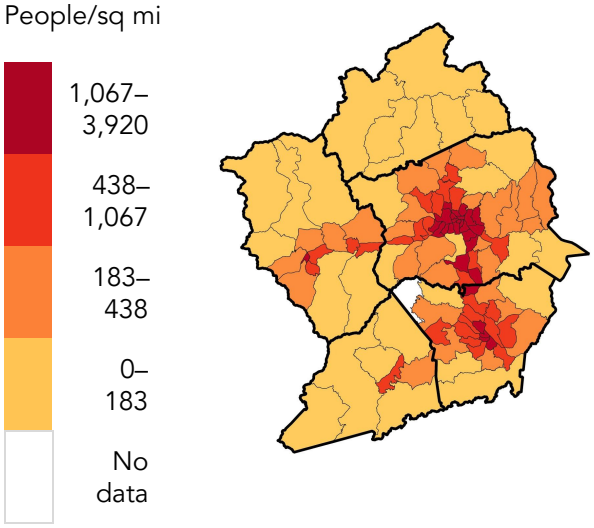


2017–2022 Population: Projected Annual Growth Rate

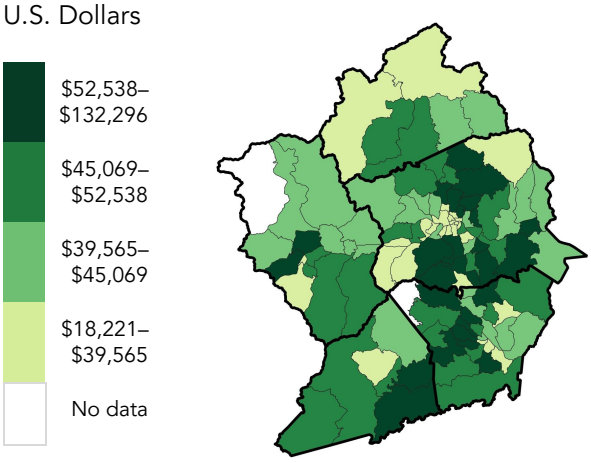


Social Vulnerability

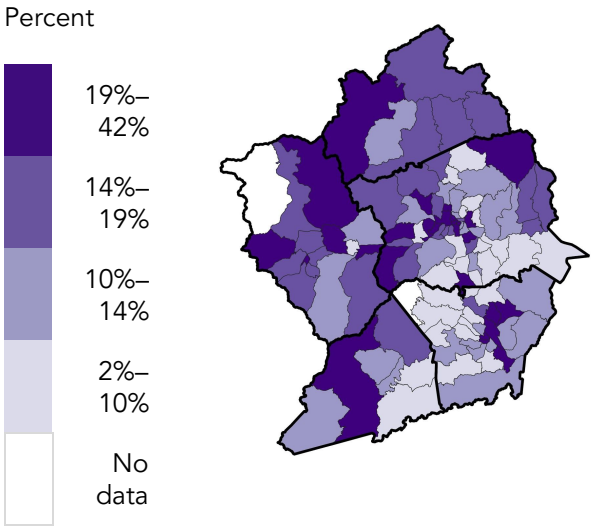
Population Density (2017)



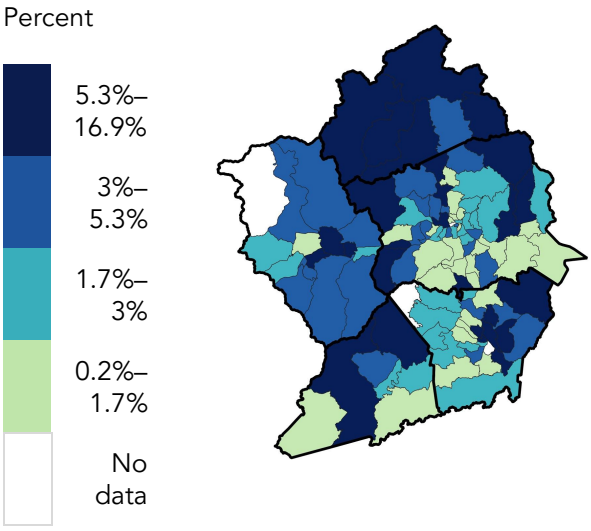
Median Household Income (2017)



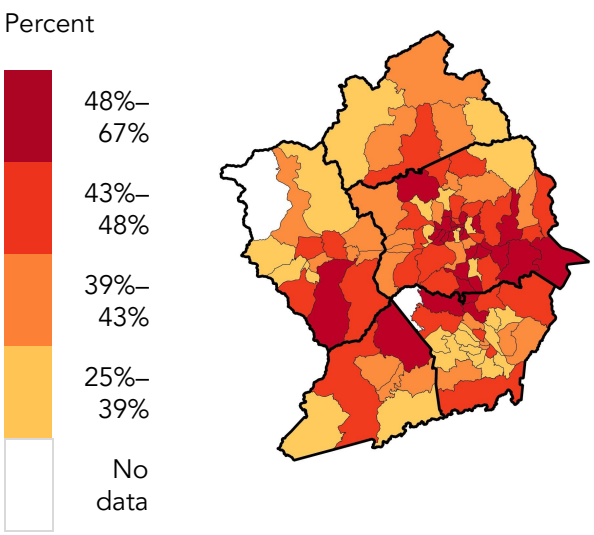
Percentage of Households Below Poverty Level (2011–2015)



Percentage of Population with Education Less Than 9th Grade (2017)

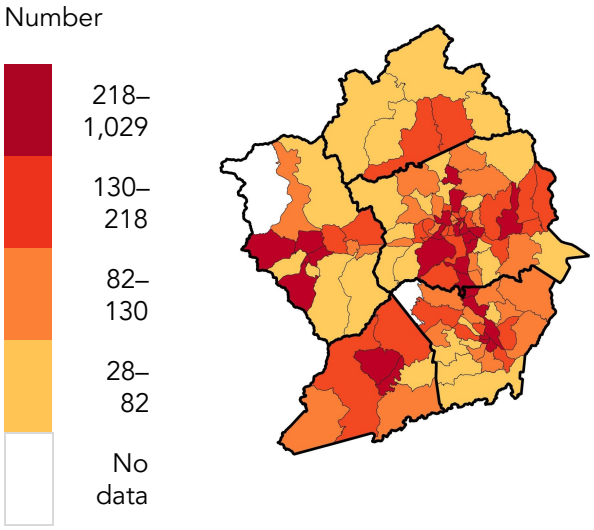


Percentage of Workers Age 16+ (2011–2015)

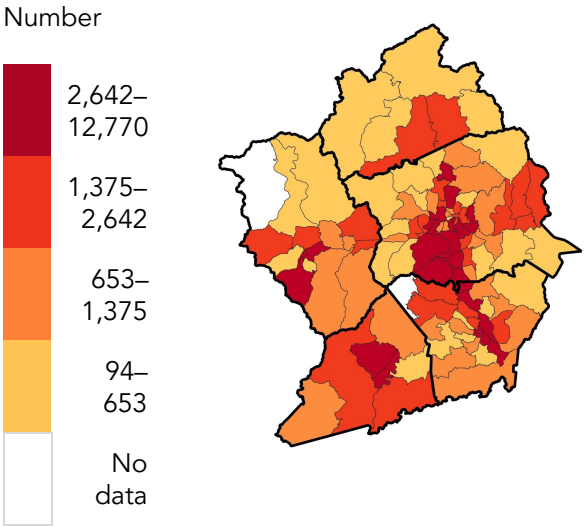


Economy

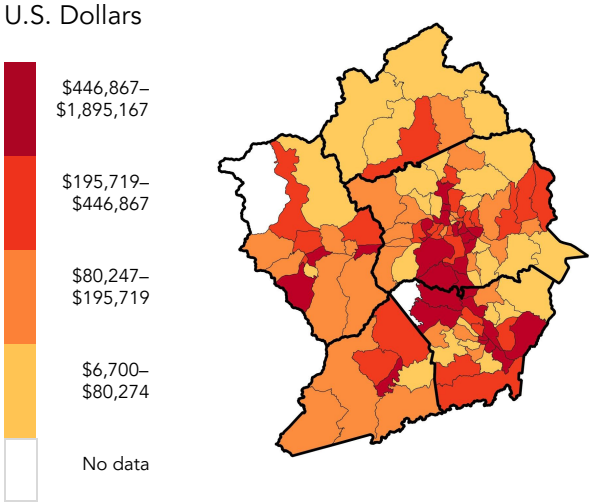
Total Businesses (2017)



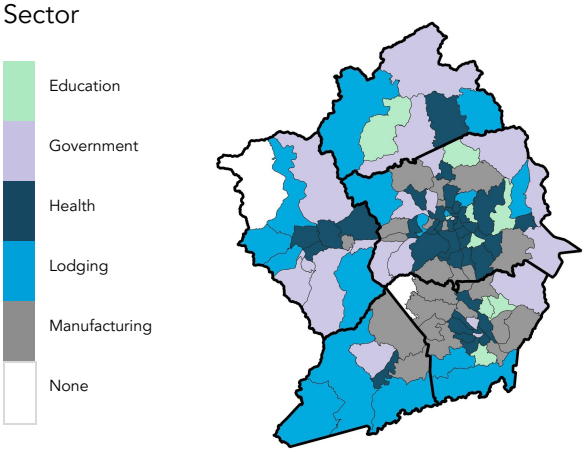
Total Employees (2017)



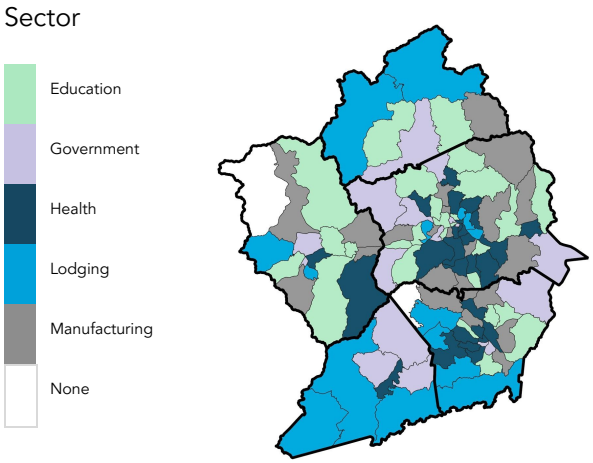
Total Sales (2017)



Majority Business Sector | By Number of Businesses (2017)

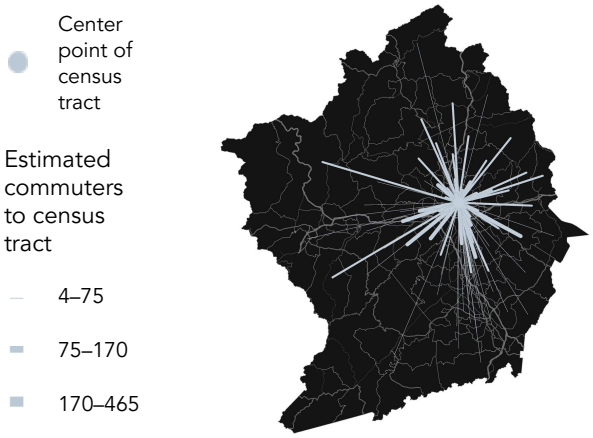


Majority Business Sector | By Number of Employees (2017)

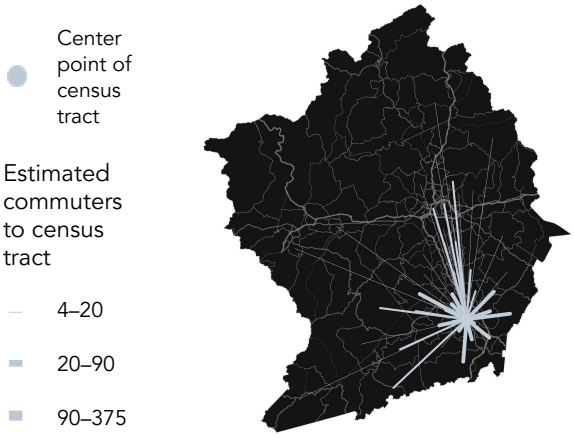


Workforce Commuting

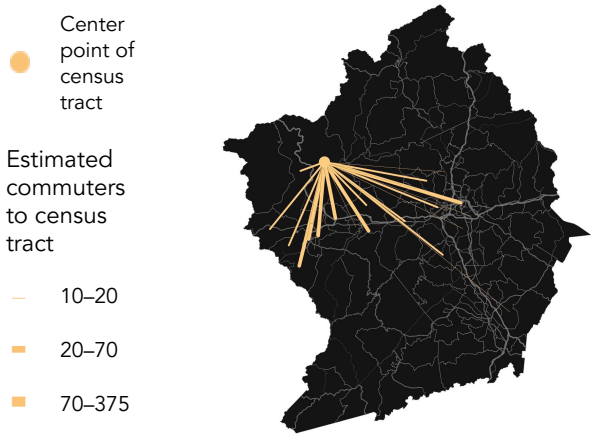
Work in Downtown Asheville (Tract 37021000100)



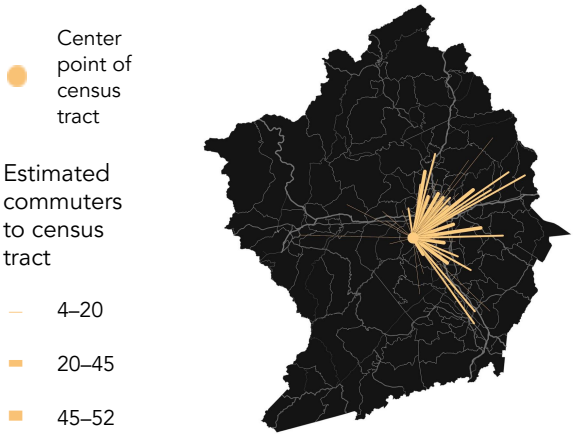
Work in Downtown Hendersonville (Tract 37089931200)



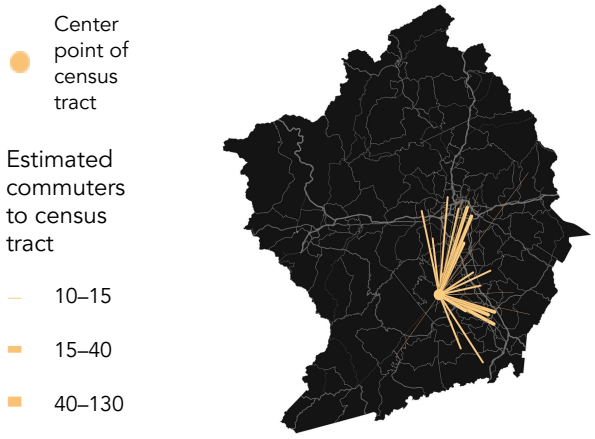
Live in Northeast Haywood County (Tract 37087920102)



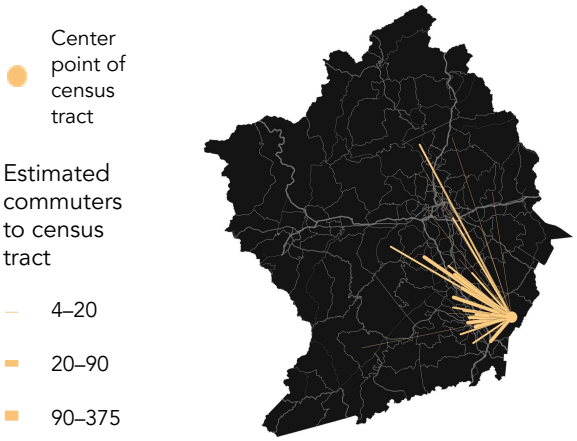
Live in Southwest Buncombe County (Tract 37021002302)



Live in Northwest Henderson County (Tract 37089930702)



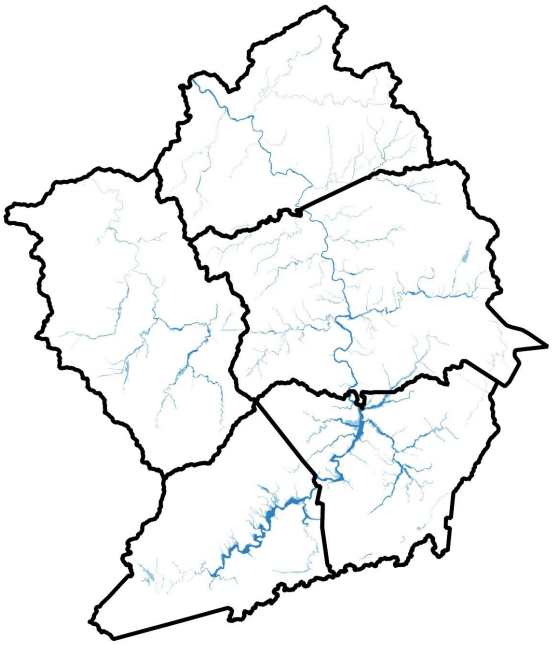
Live in Southeast Henderson County (Tract 37089930200)



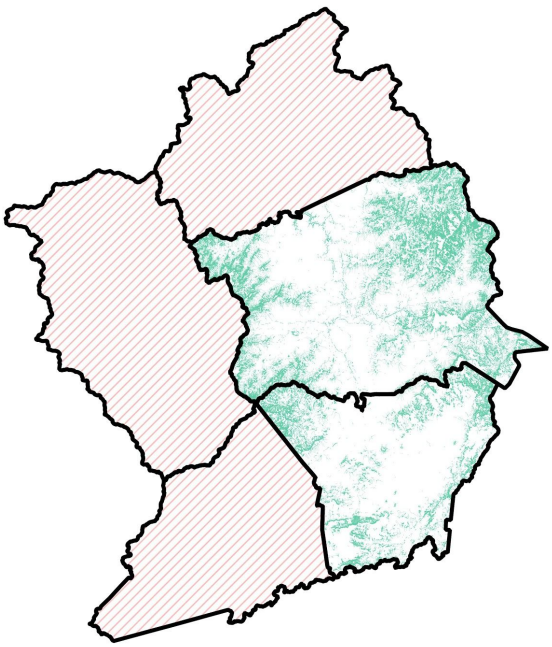
Threats

Two major threats can be mapped in detail across the Land of Sky region—flooding and wildfire—while landslides can be mapped for Buncombe and Henderson counties only. The maps below display the extent of the detailed hazard data available.

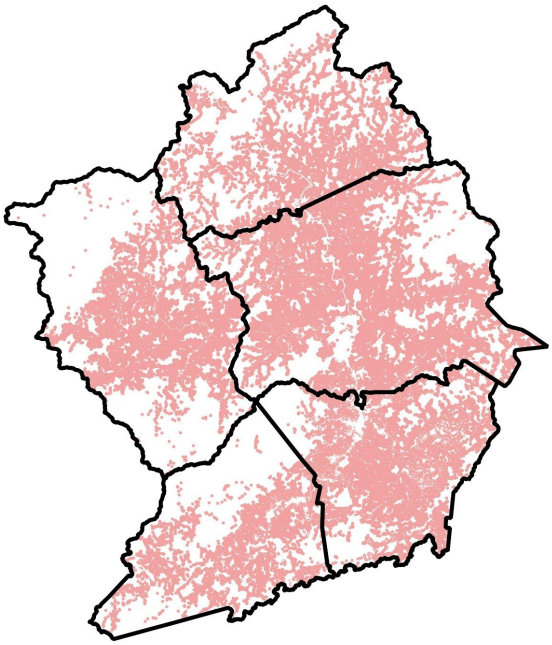
Flooding



Landslide



Wildfire



Asset-threat pair exposure

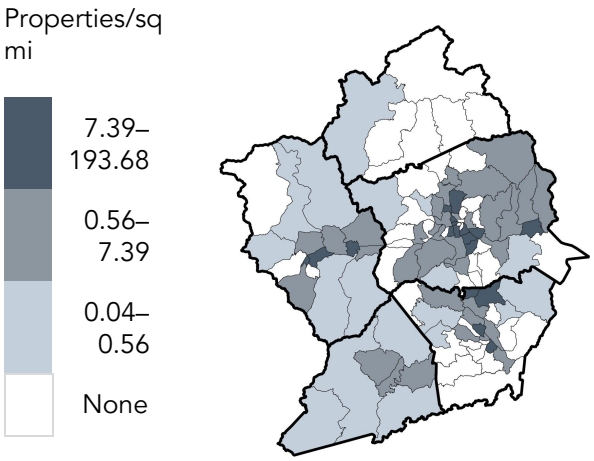
Comparing exposure across the collection of assets and threats begins to highlight the true set of issues that the Land of Sky region should address. The table below lists the number and percentage of total parcels exposed.

Asset Group	Flooding	Landslides*	Wildfire
COMMERCIAL PROPERTY (parcels)			
Industrial properties	481 (37%)	423/997 (42%)	1,191 (92%)
Institutional properties	853 (22%)	1,299/3,130 (42%)	3,517 (90%)
Office properties	270 (17%)	447/998 (45%)	1,288 (80%)
Retail properties	1,560 (24%)	1,372/4,390 (31%)	5,757 (88%)
Utility properties	155 (22%)	229/533 (43%)	538 (77%)
TRANSPORTATION (miles)			
Roads	402 (4%)	892/5,483 (16%)	N/A

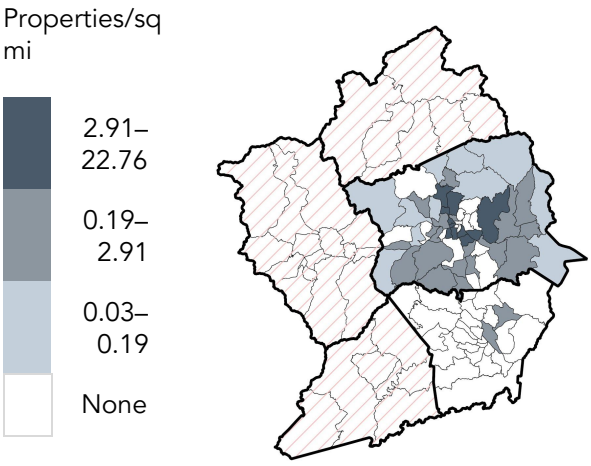
** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Industrial properties exposure

Flooding



Landslides*



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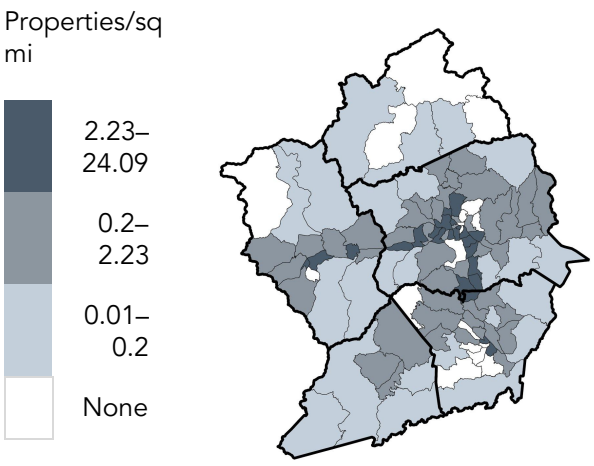
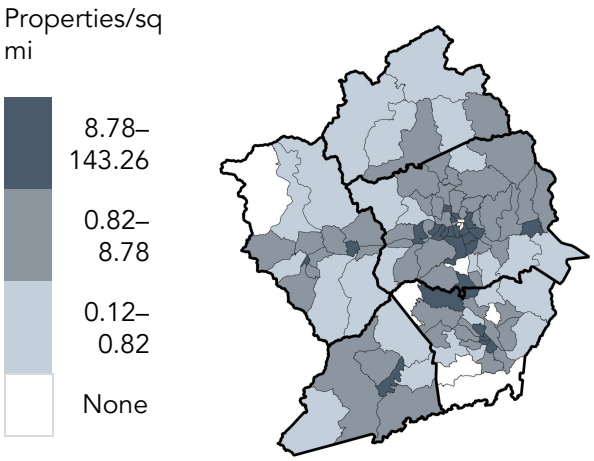


** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Institutional properties exposure

Flooding



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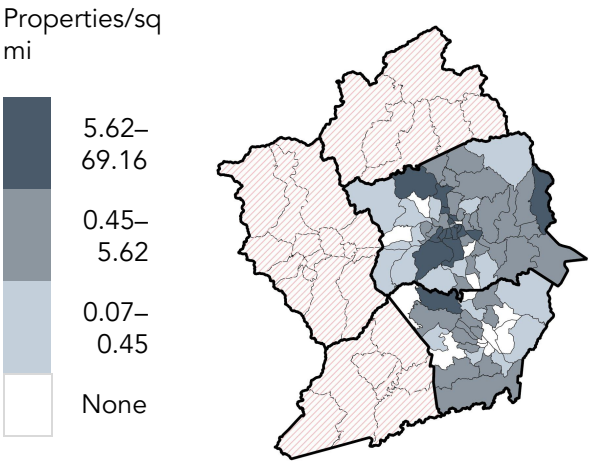

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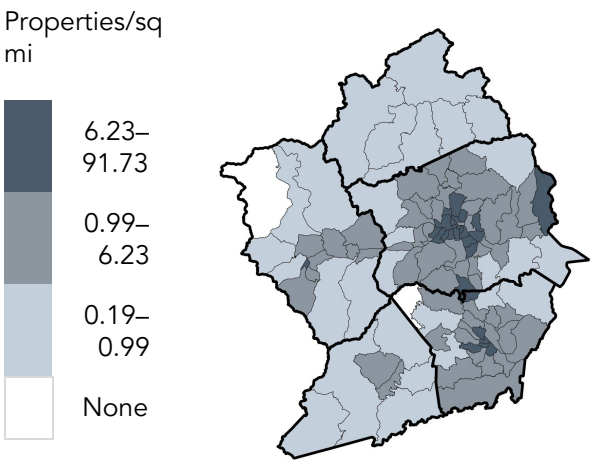
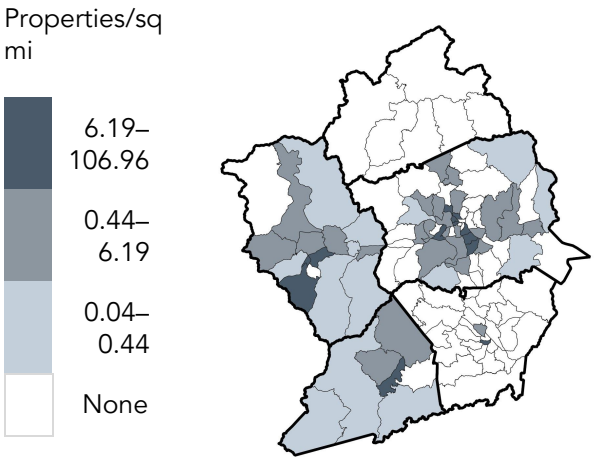


** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Office properties exposure

Flooding



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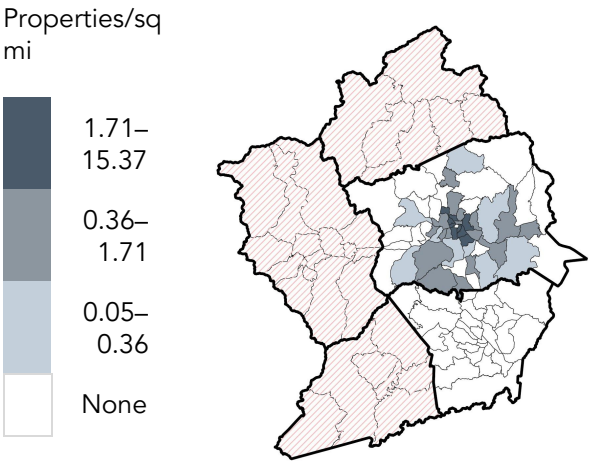

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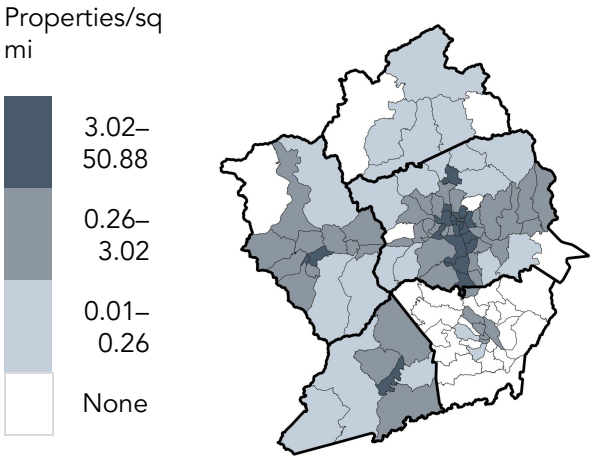
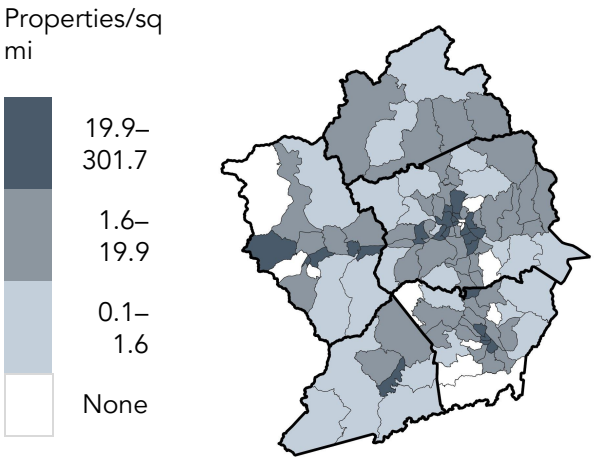


** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Retail properties exposure

Flooding



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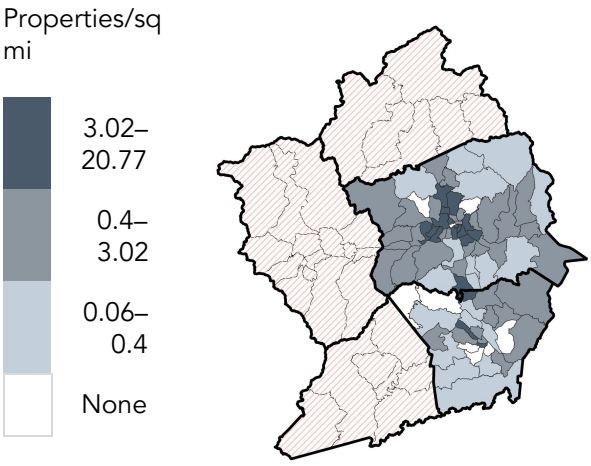

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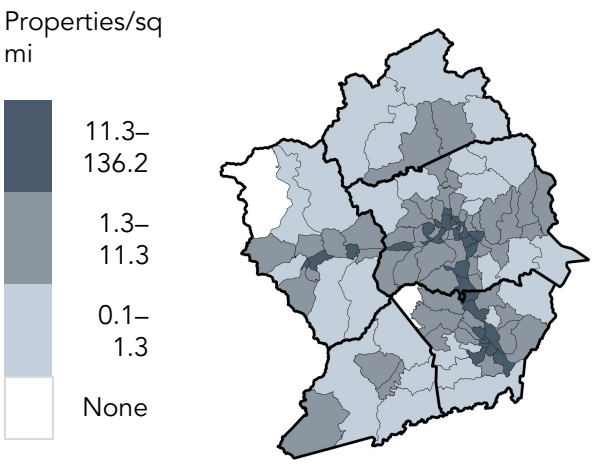
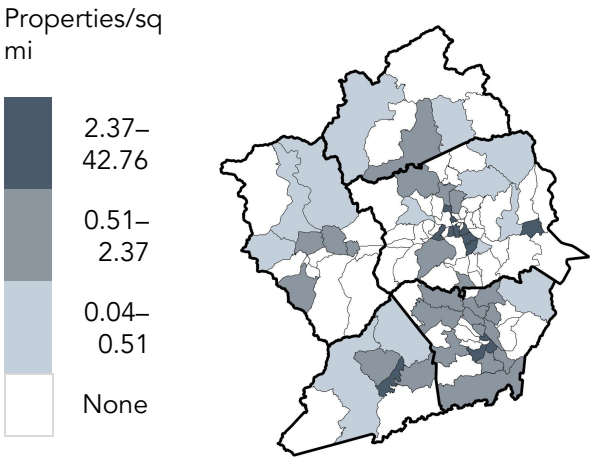


** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Utility properties exposure

Flooding



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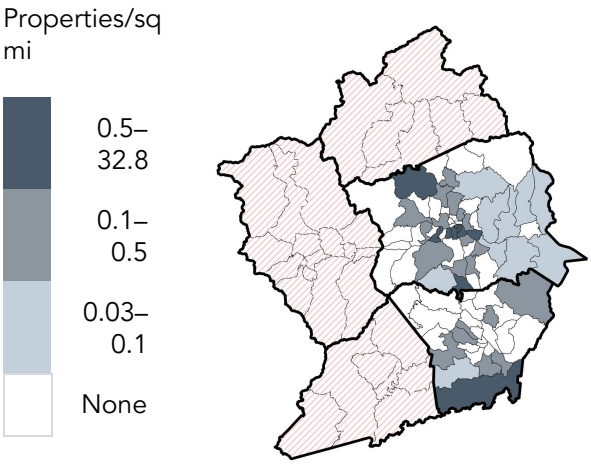

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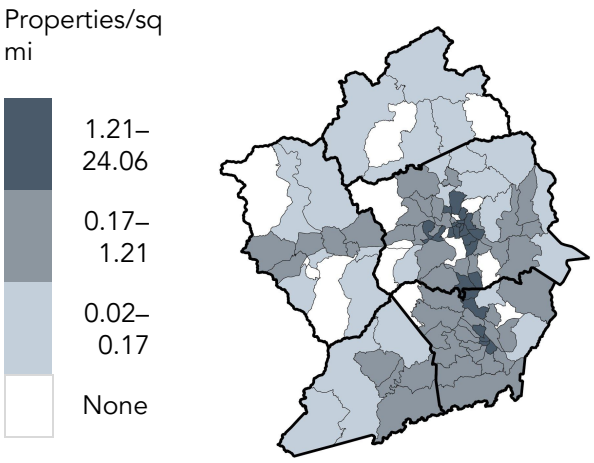
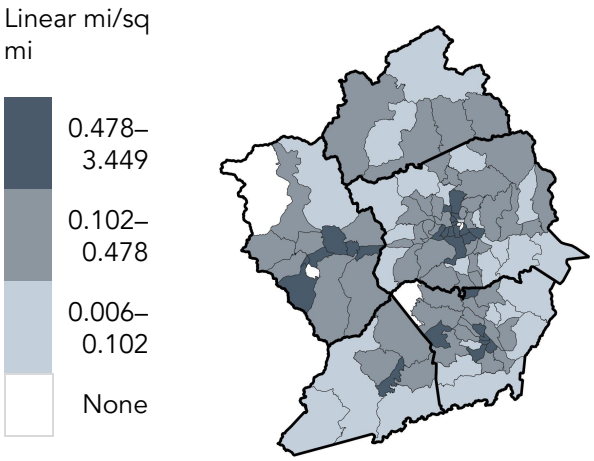


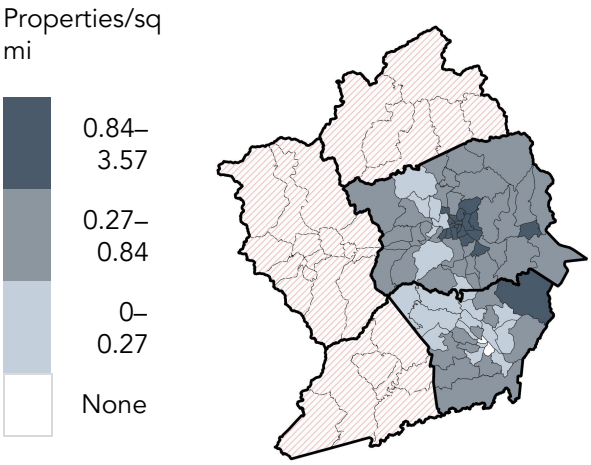
** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

Roads exposure

Flooding



Landslides*



** Note that threat model data does not cover the entire region; asset totals are for the extent of the data available (Buncombe and Henderson counties).*

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Metropolitan Statistical Area (MSA) data sources:

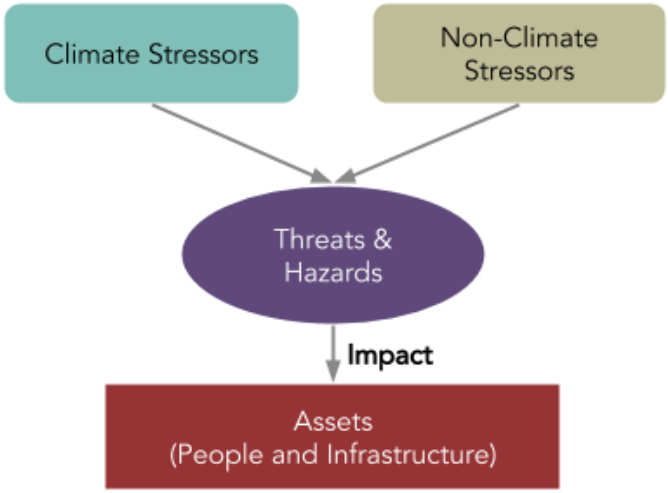
- https://www.census.gov/programs-surveys/metro-micro.html
- https://www.census.gov/population/metro/data/thematic_maps.html
- https://www.bea.gov/regional/docs/msalist.cfm
- http://proximityone.com/metros2013.htm

Appendix A: Analysis Technical Documentation

Process overview

The U.S. Climate Resilience Toolkit defines *exposure* as "the presence of people, assets, and ecosystems in places where they could be adversely affected by hazards." For purposes of this assessment, "exposure" specifically means that an asset (e.g., a structure, parcel, or roadway) is spatially coincident with a specific hazard (e.g., flooding). For example, a warehouse located within the 500-year floodplain is considered to be "exposed."

Figure 1: Exposure concept diagram



Conceptually, the hazards to which assets are exposed are affected by both climate and non-climate stressors (Figure 1). For purposes of this assessment, these hazards are presented using pre-existing hazard models, and discussion of how those hazards may change over time is presented through narrative and supporting information rather than modification of the hazard models using a variety of stressor scenarios.

The assessment was conducted in three stages:

1. Asset data normalization and categorization;
2. Spatial relation of individual assets to each hazard layer; and
3. Aggregation of exposed assets to census tracts.

Asset data normalization and categorization

As the data for asset types differs, it must first be normalized into a general shape by removing superfluous fields and ensuring that the spatial data is complete, and then categorized according to the asset's use. For this assessment, parcel data for property-based assets were categorized according to the parcel use codes attached to each parcel record. Other asset types did not require additional categorization.

Spatial relation of individual assets to hazard layers

For each asset-threat pair, we performed a spatial intersection of the asset with the hazard. Refer to Table 2 for definitions of asset types described below.

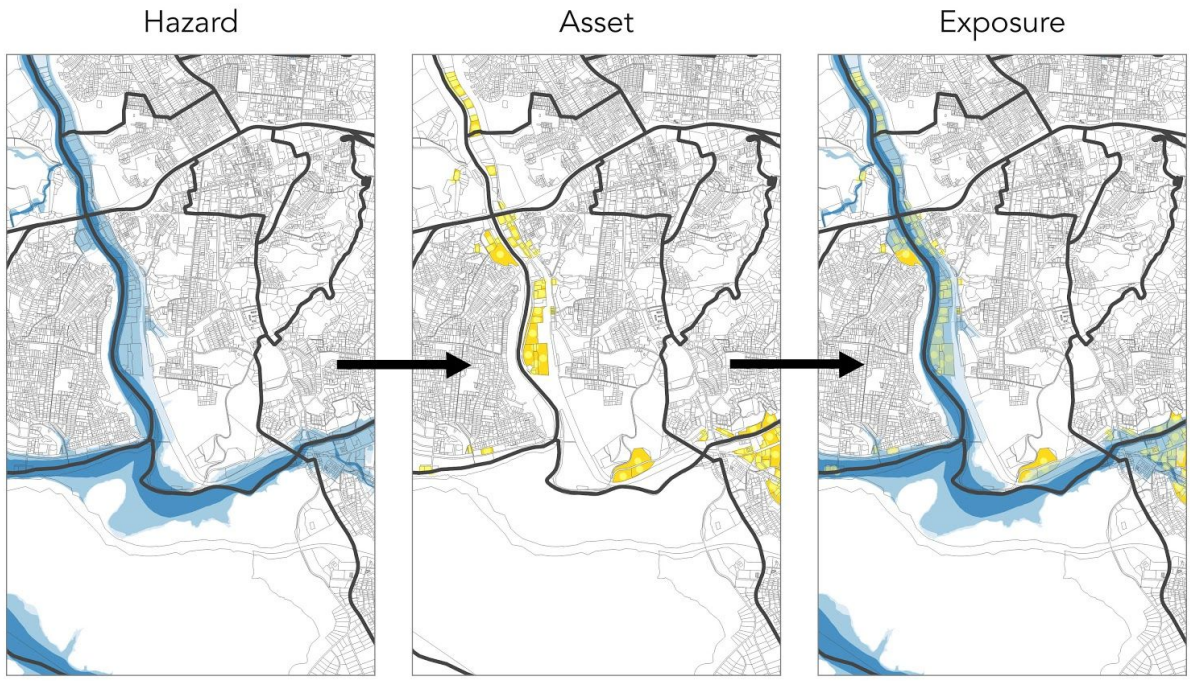
- For assets of Property Parcels type, if any part of the hazard extent fell within the extent of a given parcel, it was marked as exposed. Only the intersection of parcels to the hazard data was considered; structures were not considered for properties in the exposure assessment.
- For assets of Linear Feature type, if any part of a line segment of the feature intersected with the hazard geography, that line segment was cut at the intersection and the piece within the hazard was marked as exposed.

Aggregation of exposure to census tracts

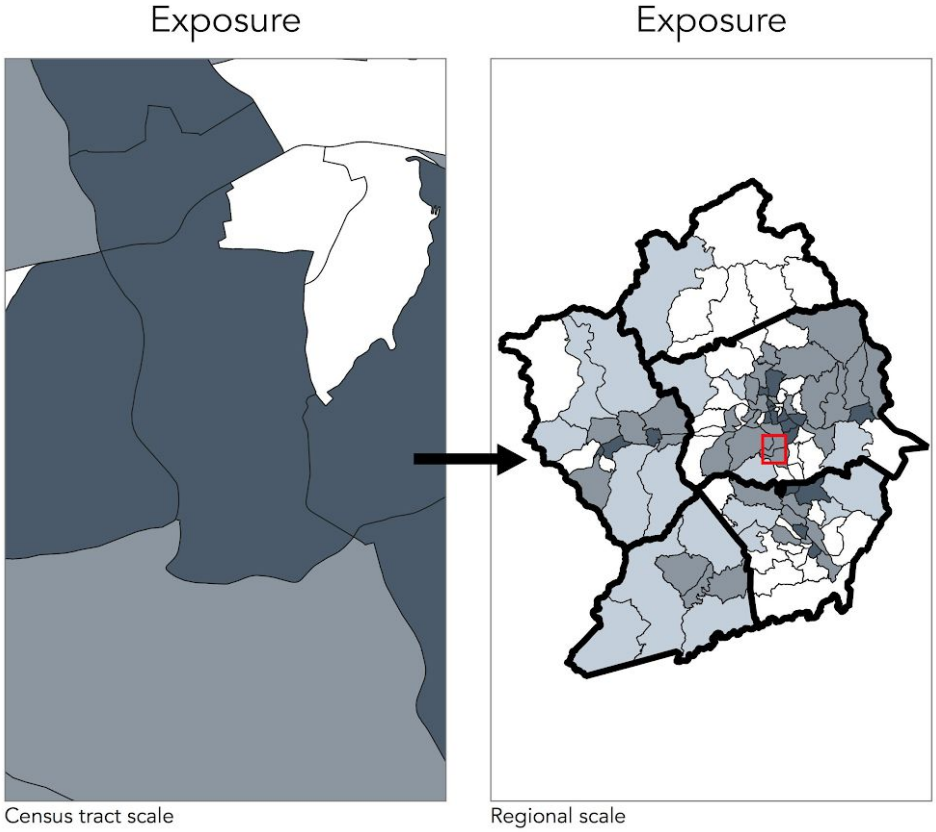
The U.S. Census Bureau defines census tracts ("tracts") as small, relatively permanent statistical subdivisions of a county or equivalent entity with a primary purpose of providing a stable set of geographic units for the presentation of statistical data.[1] A census tract generally has a population size between 1,200 and 8,000 people, with an optimum size of 4,000 people. In the assessment, tracts are used to aggregate localized analyses to the same scale as the socioeconomic variables published by the U.S. Census Bureau and Esri's Business Analyst Online (Figure 2). Using a common spatial unit for aggregation allows comparison across asset categories for a given hazard, and across hazards for a given asset.

[1] U.S. Census Bureau. "Geography: Geographic Terms and Concepts - Census Tract." Last modified 6 December 2012.

Figure 2: Industrial property/flood exposure



Asset (parcel) scale



Census tract scale

Regional scale

Data sources

Table 1: Hazard data sources

Hazard	Source	Data format
Flooding	North Carolina Flood Risk Information System	Vector features
Landslides	NCDEQ	Vector features
Wildfire	Southern Group of State Foresters	Raster

Table 2: Asset and socioeconomic data sources

Asset Group	Source	Asset Type
Industrial Property	Land of Sky	Property Parcels
Institutional Facilities	Land of Sky	Property Parcels
Office Property	Land of Sky	Property Parcels
Retail Property	Land of Sky	Property Parcels
Utility Property	Land of Sky	Property Parcels
Roads	Open Street Map | Geofabrik	Linear Features
Commute Data	Federal Highway Administration	
Economic Data	ESRI and Infogroup (via Business Analyst Online)	
Demographic Data	ESRI, U.S Census, American Community Survey (ACS) (via Business Analyst Online)	

Asset group classification

Parcel-based asset groups

All properties are extracted from ELUSE_OMEGA file geodatabase supplied by Land of Sky. Specific use types were determined by values found in the field final_trm.

Asset Group	final_trm
Industrial	IND
Institutional	HOSPTL CIVIC GOV SCHOOL SPECIAL CAMP
Office	OFFICE HIOFFC MU
Retail	SERVICE HWYRET RETAIL MALL ENT COMSTP LODGING
Utility	UTILITY
Disregarded parcels not included in the analysis	GROUP SENIOR RR VL L ML M MH H VH UH FARM WATER VACANT GRNSPC NATARA NAFBPMA CO_LINE ROW

	ROAD ROW RDROW UNK

Parcel assessment and summary statistics

Total Unique Parcels	294,684
Total parcel value*	$92,187,111,096
Total parcel improvement value*	$35,013,466,229
Assessed parcels	14,068 (4.77%)
Assessed parcel value*	$14,520,048,78 (15.75%)
Assessed parcel improvement value*	$9,289,995,270 (26.53%)
Disregarded parcels	294,684 (95.23%)
Disregarded parcel value*	$77,667,062,315 (84.25%)
Disregarded parcel improvement value*	$25,723,470,959 (73.47%)

* Parcels values do not include Transylvania County.

Non-parcel feature asset groups

Asset Group	Datasource
Roads	Open Street Map | Geofabrik